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Promoting the Generalization of Knowledge: A Developmental Approach to Teaching Metaphorical Thinking

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Successful instruction and accomplished learning has one fundamental outcome: the ability of individuals to wring out of original learning, knowledge that will have potential application in a wide range of tasks in multiple contexts.

The success with which individuals generalize from prior knowledge is often revealed in the way they co-ordinate, or order, procedural steps when confronted with a new task. For example, an individual may know how to multiply, and have considerable knowledge about fractions, angles, and even an understanding of the calculation of percentage but be unable to apply this knowledge when confronted by a new task that requires the co-ordination of this knowledge into a series of procedural steps. In a circle or pie graph, for example, students might be given information about each sector of the pie expressed as a percentage. They might be asked to transform this percentage information into a calculation of the central angle for each of the sectors. The reader may recall that the angle subtended by the arc of the sector at the centre of the circle is called the central angle. The reader may also recall that there are 360 degrees in a complete turn about a point. Given the information that one sector constitutes 12.5 per cent of the total area of the circle, the reader might attempt to order the procedural steps that would yield the central angle for that sector. I encourage the reader to

consider to what extent an understanding of the nature of the problem, the demand characteristics of the problem, influences the ordering of these solution steps.

I shall suggest throughout this paper that the generalization of knowledge requires not only specific domain understanding for operations like multiplication, calculation of percentage, etc., but also the co-ordination of these operations into a particular sequence of procedural steps at the service of the new task demands. I suggest that it is through the mental activity of metaphorical thinking that one is able to consider the new task in relation to one's knowledge bank of specific skills. I suggest that these mental activities enable one to establish the initial representation of the problem whereby the co-ordination of procedural steps is made possible.

Instructional Considerations

The generalization of knowledge is partially dependent upon the use by educators of particular kinds of instructional procedures although there seems to be little consensus as to the nature of the most effective of these procedures. For example, teaching individuals to use general thinking skills or metacognitive strategies has not met with unqualified success. The single most important "instructional confound," as I see it, turns around developmental considerations, most specifically those having to do with changes to the central nervous system. Piaget's (1970) developmental theory remains as the most powerful account yet of the psychological consequences of these alteration to the CNS. I doubt that anyone would seriously question the claim that generalization or transfer phenomena are critically influenced by changes to the CNS. The problem is how to characterize the psychological consequence of these changes to the CNS in terms of an individual's ability to understand the implication of old learning with respect to its potential use in new tasks. Or more simply, to remove the anticipation element, the problem is to demonstrate how development has a significant consequence for the process by which individuals go about comparing the "surface structures" of tasks to determine their underlying "deep structures" and on that basis to conclude that the tasks are similar in some respect.

In order to bring the developmental issue to the front of our investigations, it is absolutely necessary to specify those core or central conceptual skills that bear directly on generalization activities and to do so in a way that is sensitive to changes in the CNS. Piaget's stage progression theory, although providing a rather full description of various intellectual accomplishments, does not provide the level of detail or iteration of process skills necessary to describe how knowledge might be generalized across multiple contexts. Indeed following on Piaget's theory, the research findings for stage specific horizontal transfer across tasks demanding similar conceptual skills are mixed and at best problematic.

Two theoretical approaches that have been used to address the generalization issue have not taken into account development. They are (1) teach general skills or problem solving strategies which might transfer across classes of problems, and (2) teach specific skills across multiple contexts to observe generalization of these skills in different situations (Campione & Brown, 1984). These approaches have produced some modest successes (e.g., Feuerstein, 1980; Brown, Campione, & Day, 1981) providing evidence that cognitive rehearsal, self-verbalizations to slow down and think (Michenbaum & Goodman, 1971) and self-regulation skills, in general, are valuable in remedial situations but once again there is scant evidence that individuals acquire the conceptual skills necessary for generalizing original learning across multiple contexts. Essentially, there is lack of theoretical guidance about which concepts or strategies could yield transfer of knowledge across the widest range of tasks.

One further instructional issue concerns the extent to which situation or domain specific knowledge is important for generalization to occur. Keil (1986) has suggested that depth of knowledge within a domain is necessary before individuals will be in a position to note similarities across different domains of experience. On this account, extensive domain familiarity is not only a prerequisite for successful generalization of knowledge in multiple contexts across a wide range of tasks but may indeed be deemed sufficient. But again this view does not consider either the developmental or the co-

ordination of specific skills issues and, therefore, there is lack of theoretical guidance about the kinds of experience and mental activity that will provide the basis for the generalization of knowledge.

Theoretical Considerations

Case (1985) and Sandieson (Sandieson & Case, 1987) have addressed the problems associated with development and generalization in a stage-dependent theory analogous to that of Piaget. Each stage is characterized by the emergence of qualitative different abstract representations, which are formed as an internalized structure from the previous stage. Children's progression to higher levels of development (and ability to solve more complex tasks) is characterized as a growth in the ability to co-ordinate information processing attentional units within working memory. At the beginning stage, children can only deal with tasks which require attentional focus on single units. With development, they can focus on combination of two, then three, etc. Sandieson and Case (1987) suggest that "if a large part of the ability to solve a problem depends on the use of central conceptual skills, then knowledge and use of these skills will give a problem solving ability to students even when they might not know all the subtle details of a situation." Therefore, on this account, children are apt to generalize knowledge from one situation or task to another on the basis that these conceptual skills can be applied to new tasks and most importantly to numerous mixed domains of tasks.

The approach that Case et al. take is without question an important one in that explicit, precisely articulated models of a series of cognitive operations a child actually executes when performing a cognitive task can be offered. On this basis, it is possible to perform meticulous, detailed task analyses of mixed domains of tasks, thereby providing a powerful argument for generalization based on the common application of central conceptual skills. One criticism of this approach is that we never know in any absolute sense that a particular task analysis is correct. Alternative hypotheses always remain possible (Brown et al., 1983; Sternberg & Powell, 1983). Indeed as Kuhn (1984) suggests "... researchers engaged in tasks analyses of cognitive tasks have tended to produce as

many analyses of the same task, e.g., conservation, as there are analyzers of it." A second and more fundamental criticism concerns whether task analyses describing multiple, largely independent process are ecologically valid. Is task performance nothing but the serial execution of a specified set of individual processes? As Kuhn (1984) points out, this approach "has concerned itself predominantly with strategy execution, and scarcely at all with strategy selection." For example, how would an individual come to select a strategy that was "elegant" over one that was merely "workable"? "In order to select a strategy as appropriate for solving a particular problem, the individual must understand the strategy, understand the problem, and understand how the strategy and the problem intersect or map onto one another, which entails understanding the range and limits of the strategy's appropriate application" (Kuhn, 1984, p. 165). On this account, in order to generalize, the individual must select a strategy in one particular context and then apply it subsequently in other contexts in which it is equally appropriate. To be successful, "the individual must reflect on what he or she is doing at a level differentiated from the "doing" itself (Kuhn, 1984, p. 165).

On the foregoing analysis, a developmental theory able to respond to generalization phenomena must treat metacognitive activities substantively. By this, I mean that the theory must distinguish between performance that is constrained by underlying neurological development and performance that originates in individuals' attempts to use the various strategies that are consequent on these structural changes. We see neurological development on Piaget's conservation tasks where children shift, for example, in performance during the natural course of development from believing that quantity varies with perceptual rearrangement to believing that it is invariant. This kind of performance implies qualitative changes to belief systems primarily as a function of changes to CNS activity. Therefore, consequent on underlying neurological development, children come to acquire new knowledge in various domains of experience. They acquire new, qualitatively different strategies they did not have previously; they integrate existing strategies in new ways; they encode new and different kinds of

information and represent it in new and different ways; and they develop new forms of executive, or metacognitive, control over their cognitive functioning. On this account, a developmental theory must be responsive to the possibility for instructional interventions of one kind or another in that neurological development opens out new opportunities for instruction, including the social facilitation of more advanced concepts and strategies (see Vygotsky, 1986; Gamlin, 1988).

The key to understanding generalization phenomena would seem to reside in those metacognitive activities wherein the individual will choose to use a strategy in contexts that are not identical to the one instructed. Since these activities would necessarily be influenced by neurological development, one must take this into account. A developmental theory dedicated to providing explanatory principles for generalization would treat substantively the interaction between domain specific skill operations and the strategies derived to make use of these skills. Furthermore, the theory would treat substantively an individual's metacognitive understanding of the strategy itself, i.e., an understanding of his or her own actions independently of the actions themselves. In other words, the individual will come to understand the value and significance of the strategy, taking into account contextual considerations, as well as how to execute it. The acquisition of this appreciation, or metacognitive understanding, will more than likely be the more difficult, complex attainment of the two.

Piaget proposed that it was through equilibration that individuals develop both strategies and metacognitive strategies. An individual's performance provides feedback as to the effectiveness of these strategies and so "provides the impetus, or disequilibrium, necessary for the instruction of new strategies that will be more adequate for dealing with the tasks encountered and so leave the organism in a state of improved equilibrium with its environment" (Kuhn, 1984, p. 173). While the neurological development represented by Piaget's stages would provide the means whereby the quality of feedback would undergo progressive change, these remain rather vague descriptions that do not provide the level of specificity necessary to adequately

explain how strategies become modified by individuals during the course of the functioning of these strategies (Lerner's (1986) third source of development).

Metacognitive understanding as discussed above in relation to the generalization of knowledge to new tasks does not receive serious treatment.

A developmental theory focussed on the metacognitive activities involved in the generalization of knowledge would be robust with respect to:

1. Demonstrating that strategy selection is consequent upon an individual's representation of problem and evaluation of strategy given the exigencies of the presenting problem or situation in relation to the original learning task(s). On this account, the individual will develop an over-view or holistic view of the problem before taking action.
2. Demonstrating how instructional design, including social facilitation, can promote learning to higher levels of task complexity and across wide ranges of problems at the same level of complexity. Accordingly, an individual's over-view of the problem will be influenced by instruction.
3. Demonstrating that modifiability of strategy for purpose of accommodating to new features of the presenting problem or situation is consequent on 1 and 2.
4. Demonstrating that 1, 2 and 3 above vary qualitatively with neurological development.

Theoretical Considerations Extended

In Case's (1985) revision of Piagetian theory, the level of the child's strategy depends on the amount of attentional energy available in working memory. Early in development, even a simple strategy requires much attentional energy because each step must be monitored. Thus, a child does not have attentional energy available for holding many items in working memory. However, once a strategy has become automatic, through much practice, it no longer requires as much attention. Thus, there is more attentional energy available for holding more items in working memory so a child may move on to a more complex strategy, and so on. Increasingly sophisticated strategies develop because simple strategies become automatic, freeing space in working memory for more use in monitoring complex strategies. Research (see Chi, 1982) suggests that the holding capacity of working memory remains constant past a certain point in

development while techniques for effectively using that capacity increase with age. Chi's work suggests an alternate explanation for the observed increases in digit span performance with age: older subjects may have more knowledge and experience with techniques for grouping items. To an adult, a set of two or three numbers may be held as a single unit; to a chess player, a configuration of several pieces may be held in memory as a single unit.

On this account, cognitive development may be viewed as the acquisition of increasingly sophisticated strategies, strategies that become modified during the course of their own functioning. But the essential question remains as to whether these strategies modify "on their own" in response to new task demands or whether what is required is a kind of metacognitive vigilance over these activities such that the individual will reflect on what he or she is doing at a level differentiated from the "doing" itself. The generalization of strategies to contexts not identical to the one instructed would seem to require this latter kind of mental activity in that the individual will restructure his or her prior knowledge of the appropriateness of particular strategies on the basis of the demand characteristics of the new task. Likewise, the generalization of previously acquired specific skill knowledge would seem to require metacognitive activity to permit individuals to co-ordinate a new sequence of procedural steps when confronted with a new task. A reflective process would seem to be prerequisite as the individual considers the new task in relation to his or her knowledge bank of practiced skills.

The construct central to metacognition may be described as those mental activities that enable individuals to get to "higher ground" in that it is only possible to develop an over-view of presenting problem and old strategies and skills when "higher ground" is achieved. With instruction, the child is able to go beyond his or her "present level of development 'to achieve higher ground' and, eventually, new consciousness" (Bruner, 1985, p. 25). I explore these notions in considerable depth in another place (Gamlin, 1988) in order to better understand Vygotsky's developmental construct, 'the zone of

proximal development.' I argue that it is by getting to higher ground that individuals are able to move in the "zone" (see Vygotsky, 1978, pp. 85-86). An essential point in Vygotsky's writings is that we do not use as explanatory principle the very phenomenon that is the subject of our investigations. This would be tautological. For example, if the phenomenon of interest is how individuals get to "higher ground," we cannot say "because they become more conscious." This explanation would be tantamount to saying, as one youngster did trying to explain to me how we go about thinking about what we are thinking -- "well, we are not cows." For Vygotsky, "activity" was the explanatory principle for consciousness (see Wertsch, 1981 and especially Kozulin, 1986 for an historical - theoretical analysis of the concept of activity in Soviet psychology). Activity was the generator of consciousness: building consciousness from the outside through the relations with others. Consciousness on this view, although requiring a sociocultural matrix whereby "culture-of-all is remodelled into the verbal thought of the individual" (Kozulin, 1986, p. 2687), also is built up from the inside through a process of "exteriorization" whereby words are given new meanings as the youngster attempts to "cut new paths" from thought to external speech. Because of the "inexpressibility of thought... new paths from thought to word leading through new word meanings must be cut" (Vygotsky, 1934/1986, p. 251). The activities of inner speech, the inner dialogue, enable the individual to distinguish between symbol - from - others and symbol - for - others thereby making it possible for the youngster to "cut new paths." With instruction or "scaffolding," to use Bruner's metaphor, the tutor serves as a surrogate consciousness "scaffolding the learning task to make it possible for the child to internalize external knowledge [presumably through the activities of inner speech although Bruner does not make this clear] and convert it into a tool for conscious control" (Bruner, 1985, p. 25). With this kind of control, the individual will conceivably become more intentional with respect to "exteriorization" as a conscious activity. In any case, I argue that it is through "exteriorization" that the individual will achieve the "highest ground" (see Gamlin, 1988, pp. 29-41). This is why Vygotsky's "zone of proximal development" is so

important. The kinds of activities that occur in transactions with others are exactly those activities that produce greater consciousness, greater intellectual control and more intentional behavior, leading children on ahead in their development. I shall not review my criticism of the "scaffolding" metaphor (see Gamlin, 1988, pp. 38-41). I introduce Vygotsky's comments to make the point that in our investigations of metacognition and the generalization of knowledge, we do not make the mistake of treating metacognition as explanatory principle. Metacognition, after all, is simply another word for "consciousness."

If we are to achieve theoretical guidance about the kinds of "metacognitive activities" that are instrumental in the generalization of knowledge across multiple contexts of tasks within the same level of complexity as well as in the generalization of knowledge to higher levels of task complexity, we need a theory that addresses the metacognition issue directly. To return to an earlier point, although a compelling argument can be made for the generalization of knowledge between mixed domains of tasks based on common application of central strategic skills, we need, in addition, theoretical guidance as to the "metacognitive activity" that is the complement to these strategic, central conceptual skills.

In an important paper reviewing work on knowledge acquisition and knowledge restructuring, Vosniadou & Brewer (1987) consider the mechanisms for knowledge restructuring. One "type of restructuring is conceptualized as the product of the child's increased knowledge of a domain (brought about by the child's experience and/or by instruction)" (Vosniadou & Brewer, 1987, p. 53). This type of restructuring is contrasted with that achieved through the development of logical capabilities as exemplified in Piaget's theory and changes brought about by neurological development and global restructurings known as stages. "This type of restructuring is said to constrain children's ability to acquire knowledge in all domains and thus has been referred to as global restructuring (Carey, 1985a)" (Vosniadou & Brewer, 1987, p. 52).

Research on knowledge acquisition has suggested two different interpretations of the kind of domain - specific restructuring that can occur during learning (Carey, 1985b). Weak restructuring notions turn around novice/expert shifts in that: "First, experts represent more and/or different relations between concepts than do novices. Second, experts organize their knowledge in terms of abstract relational schemata that do not exist for, or are not easily accessible to, novices ... radical restructuring... [conceptualizations suggest that]... the novice does not simply have an impoverished knowledge base compared to that of the expert; the novice has a different theory, different in terms of its structure, in the domain of phenomena it explains, and in its individual concepts" (Vosniadou & Brewer, 1987, p. 54).

Although both weak and radical restructurings may occur during knowledge acquisition, only the radical type can account for the emergence of completely new theories or new paradigms out of existing structures. The distinction between weak and radical restructuring has obvious implications for the generalization of knowledge across mixed domains of tasks and especially in the generalization of knowledge to higher levels of task complexity. With respect to instructional issues, we must indicate to what extent our instructional goals are to help individuals achieve weak or radical restructurings and consequently the possibility for weak or radical generalizations. For example, do we want to develop instructional procedures that would enrich existing novice "theories" to help them achieve theory change or weak restructurings? On this basis, we would help children notice that common central strategic operations could be applied across a variety of tasks in multiple contexts. This mechanism for knowledge change has been discussed in the literature as schema induction, involving the discovery of the regularities in the co-occurrences of certain phenomena. In the course of making these inductions, the child creates new, high-order relations between existing concepts.

Do we want also to move beyond enrichment to help the child acquire radically new theories? The latter imperative would suggest that we need to better understand how discontinuities in learning may come about such that the child would develop an

internally consistent new paradigm; make a discovery if you will, that might radically transform the child's understanding of the way things are. On this basis, the child might begin to generalize knowledge across domains of experience that prior to the "discontinuity," would not have been attempted.

Vosniadou & Brewer (1987) suggest that there are "two candidate mechanisms for the kind of radical restructuring that may occur in children's acquisition of domains These two mechanisms are (a) Socratic dialogues; and (b) analogies, metaphors, and physical models" (Vosniadou & Brewer, 1987, p. 61). With respect to Socratic dialogues, Vosniadou & Brewer believe that "actual restructuring must grow out of the attempts of the socratic teacher to guide the child to construct the new schema.... There is now a promising body of research that attempts to develop instructional techniques... that involve an active teacher who is interested in understanding the students' point of view, proposing alternate frameworks, creating conceptual conflict, and leading students into constructing conceptually consistent theories of the domains (Vosniadou & Brewer, 1987, p. 61). With respect to analogies and metaphors, Vosniadou & Brewer (1987) suggest that "... one way old knowledge can be brought to bear on the construction of a new schema or the restructuring of an existing one is by using analogies and metaphors from a different domain. Analogies can play different roles in restructuring. They can facilitate both the spontaneous restructuring of new schema, and the explicit teaching of a new structure to children or adults ... both adults and children can use an analogy to transfer information from a known domain to help construct a new schema or restructure an existing one... [even though] the spontaneous use of analogy... [is] very difficult to achieve in experimental situations either with children or with adults" (Vosniadou & Brewer, 1987, pp. 61-62).

Metacognition Reconsidered

Metacognitive "activity" is that activity which occurs when children achieve "higher ground" by either restructuring their prior knowledge in the weak or radical senses described above. On the foregoing account, children are most conscious and most

intentional as they attempt radical restructuring involving fundamental changes in schemata. The mechanisms of this mental activity may very well be the thinking required in socratic dialogues as well as the thinking in analogy and metaphor when information is transferred from a known domain to help construct a new schema or restructure an existing one.

It would seem to be necessarily the case that in order to achieve either weak or radical restructuring of knowledge, individuals would need to reflect on their existing knowledge base as they attempt to make use of various "scaffolding" procedures like the socratic method, analogy and metaphor, introduced by knowledgeable others (see Bruner, 1985 and Gamlin, 1988 for a critique). The generalization of knowledge then would rest not so much on the perception of common "deep structures" across tasks but more fundamentally on the mental activities that would establish the legitimacy and fruitfulness of the (weakly or radically) new schemata for linking what had previously been considered to be disparate domains of experience. It is precisely this kind of reflective activity that would enable the most radical kinds of generalization of knowledge from one order of complexity of tasks to much higher orders of complexity of tasks differing greatly in both "surface" and "deep structure" characteristics. It is the perception of similarity between these disparate domains which is crucial. And, it is precisely those metacognitive activities that enable individuals to make use of instructional metaphor or analogy linking disparate domains that are at the centre of our investigations.

Similarity Thinking: The Theory

In order to make use of instructional analogy and metaphor, individuals must of course be able to think metaphorically. On this account, metaphorical thinking may very well comprise the metacognitive activities in the generalization of knowledge that are operative as the individual considers disparate domains and the demand characteristics of both, thereby coming to use strategies in contexts that are not identical to the one instructed.

With this approach, the phenomenon in question, i.e., the development of metaphorical thinking forms the subject matter of the theory. This approach is different from one which would attempt to establish a grid of tasks that would make differential demands on these as yet not well understood metacognitive conceptual skills. As a first step, the subject of our investigations is precisely those metacognitive activities that make generalization possible across multiple and "disparate" contexts.

In order to respond to neurological development, a typology of tasks was established based on a skills analysis of the construct - metaphorical thinking - such that several qualitatively different types of thinking were identified, organized into a hierarchy of complexity of types. One essential characteristic of the typology is that for each skills level some degree of metaphoricity is present. A related characteristic of the typology is that for each skills level some degree of generalization is required. Consequently, for the highest level metaphor tasks, there are simplified versions which younger children are able to solve. There is an important instructional advantage to this approach. If children failed particular versions of the tasks at lower levels of the typology, even though they were successful with higher level tasks, one could conclude that there was only a specific knowledge and/or practice deficit and, on that basis, proceed to take remedial action.

In addition to establishing several types of similarity thinking tasks varying in metaphoricity and hence in the degree to which generalization is possible, an infrastructure of within type tasks was constructed. We are thus able to investigate the attainment of within type concepts from simplified versions of tasks assessing a particular type of similarity thinking, to more difficult versions of these tasks. It is possible that children will solve simpler tasks at higher levels of the typology but fail more difficult tasks at lower levels of the typology. Again, we would attribute these results to specific knowledge and/or practice deficits rather than to capacity or conceptual problems. The importance of the typology of tasks requires considerable emphasis. Since the central construct is realized in some degree in each task in the

hierarchy of tasks, performance can be described with reference to the developmental scale represented by the range of lower to higher order tasks. On this basis, competence can be described as a point on the developmental scale. Furthermore, and with reference to Vygotsky's "zone" notions, it is possible to provide precise measurements of movement in the zone, when the zone of future development is mapped out in accordance with the developmental scale. An instructional format that would produce the most radical restructuring of knowledge and consequently the most movement in the zone would possibly involve using socratic procedures. However, we have had considerable success simply pointing to the criterial information (see Savron, 1988; Gamlin & Ash, 1987).

On the basis of this research, we conclude that instruction in metaphorical thinking does produce movement in the "zone." Consequently, emergent metacognitive activities will enable children to achieve "higher ground" thereby enabling the generalization of knowledge to higher levels of task complexity and across wide ranges of problems at the same level of complexity. Our program of research will establish to what extent these claims are valid.

One of the most compelling implications of this theory is that even very young children are viewed as having some capacity for understanding metaphor. Therefore, the metacognitive activities described above cannot be understood as emerging in an all-or-nothing fashion. The generalization of knowledge even for very young children requires a degree of intentional cross domain comparison behavior (see Gamlin, 1978). Recent work on three and four-year-old children's understanding of metaphor provides supporting evidence that they are able to understand cross-domain linkages implying high levels of metaphoricity, when these domains are disparate and when there are no visually apparent similarity criteria present (see Vosniadou & Ortony, 1983; Epstein & Gamlin, 1987).

Similarity Thinking: The Typology of Tasks

Type 1: Session 1

Subtasks(a)

Insert Figure 1 about here

The task shown in Figure 1 requires the youngster to consider four pictures and then order them relative to the target picture. The instruction is: put one of these (four) here (in the box next to the target) that is "most like" this one (the target). The youngster's selection is turned over. This procedure is repeated for the second, third and fourth selections which are put in successive boxes. In this way, all selections are compared to the target picture and not only to the last choice. These instructions can be communicated nonverbally by simply pointing to the pictures, the target and the empty box. This procedure is repeated for the second item shown in Figure 2. For both items, pictures are ordered in progression from most to least of the criterial information when that information is heaviness of outline or intensity of shading.

Insert Figure 2 about here

Data from these tasks provide three kinds of information about the mental activities that are used in the generalization of knowledge. First, even though the pictures are not identical, some children as young as 2.5 to 3.0 years of age are able to understand that they are similar in degree. Second, these youngsters are able to order the pictures, in relationship to the target, according to a "most like" criterion, even when the instruction may not be given verbally. Third, discrete unit "features" information is not available which suggests that these youngsters are using global perceptual information to order the pictures into a continuum, most to least like the target. The significant conclusion one can derive from these results is that very young

children seem to understand that objects can be grouped even when they are not identical. This is an early form of generalization which serves the purpose of "linking," in this case, a rather large and disparate picture domain. These youngsters are able to notice the old in the new (pictures) as well as develop a substructure of "relationship" between the elements in the domain. Obviously, this is not class inclusion in the Piagetian sense. Nevertheless, these youngsters, in the course of using the mental activities of generalization, are engaging in a rudimentary type of metaphorical thinking enabling them to acquire domain knowledge as well as a knowledge of the operations that establish the substructure of relationship between the picture elements. This is knowledge restructuring, at the very least, in the "weak" sense proposed by Vosniadou & Brewer (1987).

Subtasks(b)

 Insert Figures 3 and 4 about here

The tasks shown in Figures 3 and 4 require youngsters to order pictures from least to most of the criterial information when that information is heaviness of outline or intensity of shading. We want to observe whether children have difficulty adjusting to these new task demands having just completed subtasks(a).

Subtasks(c)

 Insert Figures 5 and 6 about here

The tasks shown in Figures 5 and 6 require youngsters to use the middle value of the domain as the target. The procedure is somewhat different in that the child is instructed to place a picture in the box on one side of the target and subsequently in the box on the other side. As before, after a selection is placed in a box, it is turned over. We see in youngster's performance whether they are able to simultaneously consider the

instruction and the continuum concept. For example, very young children often "build" a continuum around the target picture. They begin as before with a picture "most like" the target but when they move to the other side of the target, they continue with a picture further along in the continuum that is "most like" their first selection, rather than selecting a picture "most like" the target. They do so even though their first selection has been turned over. We think this result means that very young children have difficulty constructing the over-all continuum as they struggle to attend to the instruction requiring them to relate their selection to the middle value in the domain. If youngsters have a thorough grasp of the continuum concept, subtasks(c) should pose no difficulty. With continuum concept acquisition, youngsters have come to "higher ground" in their understanding of the mental activities that were brought to bear in the course of establishing the domain.

Subtasks(d)

 Insert Figures 7 and 8 about here

The tasks shown in Figures 7 and 8 again require youngsters to use the middle value of the domain as the target. In these tasks, however, each picture is different in respect to outline and label but similar in respect to the criterial information.

Youngsters must disregard differences in favour of the domain defining criteria. We find that some 4.0 and 5.0 year olds are able to use the requisite generalization skills needed to "link" these disparate pictures into one continuous domain. Consequently, we describe subtasks(d) as requiring the highest level Type 1 metaphorical thinking. One final point: Instructions for each of the subtasks a, b, c and d can be communicated nonverbally suggesting that a modest degree of instructional mediation will produce gains in Type 1 thinking.

Type 1: Session 2

In session 2 youngsters must consider two tasks simultaneously. These are tasks from session 1 that the youngster has worked through before. Three pairs of tasks are presented.

The first pair of tasks is comprised of one item from subtasks(a) and one item from subtasks(b). The criterial information is ordered from most to least in subtasks(a) and from least to most in subtasks(b). The youngster is required to alternate between these tasks after each move. We are able to determine ease of adjustment to shifting task demands.

Insert Figure 9 about here

The second pair of tasks is comprised of one item from subtasks(b) and one item from subtasks(c). The youngster must alternate between a task where the target is located at the end of the continuum and one where the target is in the middle position.

Insert Figure 10 about here

The third pair of tasks is comprised of one item from subtasks(c) and one item from subtasks(d). Both targets are located in the middle position but subtasks(d) contains pictures that are different in shape and label.

Insert Figure 11 about here

Type 2: Session 1**Subtasks 2(a)**

 Insert Figure 12 about here

The task shown in Figure 12 requires youngsters to consider discrete unit information as they relate pictures to target, given identical instructions to those for Type 1 tasks. We want to understand to what extent youngsters use feature-analytic procedures as they attempt to construct the domain continuum. Feature-analysis would yield a number of different features for each picture. One further question is whether children will attempt to use counting procedures, i.e., attach a numerical tag to each feature as a strategy for summing the total of these features for each picture. Such a strategy would enable them to order the pictures from most to least on the basis of the number of features contained in each picture. The second item in subtasks 2(a) is shown in Figure 13.

 Insert Figure 13 about here

We were particularly concerned to develop subtasks 2(a) items in such a way that youngsters could continue to use Type 1 thinking and their global perceptions to order the pictures. In this way, we observe children in transition with respect to Type 1 and Type 2 thinking.

Subtasks 2(b)

The tasks shown in Figures 14 and 15 tend to highlight the importance of feature-analytic procedures in that the discreteness of the information presented in the pictures is more obvious.

 Insert Figures 14 and 15 about here

One would expect that youngsters would be more likely to apply counting procedures to individual features because it is more difficult to make distinctions between the pictures based entirely on global perceptual impressions. For subtasks 2(b), youngsters must order the pictures from those having least (fewest features) to those having the most (features).

Subtasks 2(c)

The tasks shown in Figures 16 and 17 have the target picture in the middle position.

 Insert Figures 16 and 17 about here

As for Type 1(c) tasks, youngsters are required to alternate between one side of the target and the other. And as before, a picture is turned over once it has been selected and placed in the box.

Subtasks 2(d)

The tasks shown in Figures 18 and 19 require the child to understand that the same amount of something can be divided up into a number of different parts.

 Insert Figures 18 and 19 about here

In Figure 18, for example, the number of stars remain constant for each picture. This is supposed to signal that the same amount of substance (in this case chain-link) is present in each picture. However, the number of units (in this case links) varies in each picture. Children must apply Gelman's "abstraction principle" to the array (see Gelman & Gallistel, 1978, Chapter Nine). They must understand that number tags can be

attached to anything, in this case, to the links, irrespective of the total amount of substance (chain-link). In order to apply the "cardinality principle," that the last number represents the numerosity of the set, children must also come to grips with the observation that in this task the amount of chain-link remains the same no matter how many different ways it might be divided up. In other words, youngsters will come to understand that the number of links in each picture must be considered separately from the observation that there is the same amount of chain (substance) in each picture. They will have to do this before they will be able to order the pictures into a continuum using the "cardinality principle" and the middle picture as the target. This task is difficult for young children because they often equate numerosity with amount. For example, three-year-olds will often prefer having 5 pennies to one dime even though you might show them that having one dime is "the same as" having ten pennies. It is exactly the concept of "identity" that Bruner and others have argued is at the centre of Piaget's concrete operational thinking. The amount remains "the same" no matter how it is transformed, either perceptually (e.g., by placing it in different shaped containers if it is a continuous substance like water), or quantitatively (e.g., by spreading parts out; making different size parts), if it is a substance that can be divided into discrete units. The point of all of this for the generalization of knowledge is that the ability to notice that there is a resemblance between the old and the new (in these tasks, a resemblance that would enable a youngster to join pictures of chain-link and boxes) often is the result of changes to the CNS affecting the way individuals think. Instruction will have an impact on an individual's ability to generalize but only in-so-far as it is sensitive to these kinds of neurological developments.

Type 2: Session 2

In session 2 youngsters are once again given two tasks simultaneously. And, once again, these are tasks from session 1, except for two exceptions described below. Five pairs of tasks are presented.

The first pair of tasks is comprised of both items from subtasks 2(a). However,

one 2(a) item uses a "least" target while the other uses a "most" target. Youngsters are required to alternate between the tasks.

 Insert Figure 20 about here

The second pair of tasks is comprised of both items from subtasks 2(b). One of the 2(b) tasks uses a "least" target while the other uses a "most" target. Youngsters must alternate between the tasks.

 Insert Figure 21 about here

The third pair of tasks is comprised of both items from subtasks 2(c). One of the 2(c) tasks has a "least" target while the other has a "middle" position target. Youngsters must alternate between the tasks.

 Insert Figure 22 about here

The fourth pair of tasks is comprised of one item from subtasks 2(d) with the target in the "middle" position and a new item similar to the 2(c) subtasks with the target in the "middle" position. Youngsters must alternate between the tasks.

 Insert Figure 23 about here

The fifth pair of tasks is comprised of one item from subtasks 2(d) with the target in the "middle" position and a new item with the target in the "middle" position. The new item requires the use of feature analytic and counting procedures but, in addition, youngsters will engage in "joining" activities that are influenced by the "pattern" of information conveyed across the entire picture domain. The new task, therefore,

foreshadows Type 3 thinking. Youngsters must alternate between the tasks.

 Insert Figure 24 about here

Type 3

The task shown in Figure 25 requires youngsters to consider target information to pull out a pattern rule. They are instructed to: "Make the path longer by using up all the pictures."

 Insert Figure 25 about here

This instruction can be communicated nonverbally by pointing. Type 3 tasks are matrix tasks that require youngsters to think inductively. The abstracted rule is the basis for joining different pictures to the target. Consequently, the generalization of knowledge occurs according to the matrix rule which establishes the domain and those pictures that can belong to it. Although counting procedures may be used in some of the tasks shown below, they are used as an ancillary function in Type 3 thinking, to confirm, rather than to provide direction. As with the previous types of thinking, youngsters proceed on the basis of the similarity between the pictures, not identity matching. Although youngsters may have some success matching identical features across pictures in subtasks 3(a) on the basis of trial-and-error procedures, they will be unable to proceed exclusively on this basis for the remaining subtasks because they will increasingly have to "plan ahead" in order to use up all the pictures. Consequently, Type 3 subtasks reveal to what extent youngsters are able to use those metacognitive activities that make it possible for them to "plan ahead." They will understand that when more than one picture could possibly follow next in "the path," it is imperative that the remaining pictures be assessed with respect to their being "used up." Youngsters must, if you will, be alert to maintaining the integrity of the domain. This kind of "overview" or holistic

thinking is fundamental to being able to succeed with the various Type 3 subtasks.

Subtasks 3(a)

Figures 25, 26 and 27 show subtasks 3(a).

Insert Figures 26 and 27 about here

Subtasks 3(b)

Insert Figures 28 and 29 about here

Figures 28 and 29 show subtasks 3(b). Youngsters will discover that more than one picture could possibly follow next in "the path."

Subtasks 3(c)

Insert Figures 30 and 31 about here

The tasks shown in Figures 30 and 31 require youngsters to begin from a target located in the middle of the domain. They are required to "make the path longer" by selecting a picture for the box on the right of the target, then alternating to the box on the left of the target, and so on. They will discover that one picture could fit in two positions (boxes). They must choose the picture that will make it possible to use up all the remaining pictures.

Subtasks 3(d)

Insert Figures 32 and 33 about here

The tasks shown in Figures 32 and 33 require youngsters to once again alternate

about the middle target, beginning with the box on the right, in order to make "the path longer." These tasks require youngsters to "think ahead" across an even greater number of position possibilities in order to incorporate all of the pictures in the domain.

Subtasks 3(e)

These tasks (not shown) are drawn from Grace Arthur's Stencil Design Test. Youngsters are shown a multi-coloured geometric design picture. They are also shown a number of stencils (21) which when superimposed on one another in the correct order will yield the design. The design pictures vary in difficulty requiring from 2 to 7 stencils to make up the over-all picture. Youngsters must consider the design picture as they attempt to reconstruct it by putting the stencils in the correct order. They must "think ahead" to the desired outcome even as they apply various strategies to the individual stencils. Youngsters develop a holistic view of the problem even as they work with the constituent parts of the domain.

Type 4a

Insert Figures 34 and 35 about here

Type 4a tasks are perceptual matrix analogies. Figures 34 and 35 show tasks that are "partial" analogies in that the "A" and "B" terms are identical. However, youngsters will apply the identity rule to the "C" term if they are able to think analogically. If they are not thinking by analogy, they are very likely to select a picture that is identical to the "A" and "B" terms. Instructions to youngsters can be conveyed nonverbally by pointing to the "A" and "B" terms two or three times; then pointing at the "C" term and the empty box which is the "D" term. Immediately following "C" term and the empty box, "D" term comparisons, the response alternatives are indicated by pointing back and forth between the empty box and each of the alternatives.

As for Type 3 tasks, youngsters will achieve domain integrity as they apply the

rule relating the "A" and "B" terms. Type 4a analogy tasks assess the extent to which youngsters are able to apply the rule to a more disparate domain, represented in these tasks by the "C" and "D" terms. A holistic understanding of the interrelationships between the various terms of the analogy result in the emergence of a much more comprehensive domain structure. Again as for Type 3 thinking, this is an example of strategies modifying strategies at the behest of metacognitive activity. Since the basis for the over-all similarity relationship between the terms in Type 4a tasks depends on the use of similarity criteria that are not visually apparent, a higher level of metaphoric activity is required for Type 4a as compared to Type 3 tasks. This can be observed in Figures 36 through 42 since the identification of the rule relating "A" and "B" terms requires considerable inferential activity. Consequently, the over-all metaphor relating all of the terms in the analogy is more complex.

 Insert Figures 36 - 42 about here

Type 4b

The task shown in Figure 43 demands that the youngster has achieved the "highest ground" in that the most "conceptual leaping" (see Kogan, Connor, Gross, & Fava, 1980, on this point) is required.

 Insert Figure 43 about here

Especially promising is the possibility for "restructuring" the original learning task. For example, the task in Figure 44 uses the same pictures as the task shown in Figure 45 but the "A", "B", and "C" terms are different. Consequently, the over-all metaphor relating all the terms in the analogy is different.

 Insert Figures 44 and 45 about here

Again, Type 4b metaphoric analogy tasks can be communicated nonverbally. Having experienced Type 4a perceptual matrix analogy tasks, youngsters, some of whom are 7 and 8 years old, seem to understand the nature of analogy tasks per se at least with respect to the kinds of comparison processes that are required. Consequently, they seem able to devote considerable attention to the concepts represented in each term of the analogy problem. As a result, even young children with some help are able to articulate the rules "linking" the various elements of the problem. Figures 46-48 show the remaining sequence of Type 4b tasks.

 Insert Figures 46 - 48 about here

Previous Research: Psychometric Properties of the Typology

An earlier version of the typology of tasks was given to thirty-five South Korean students, between the ages of five and twelve (see Gamlin, 1986). Nonverbal instructions were administered followed by verbal prompts (in Korean) when necessary. The Hoyt's estimate of reliability was .80 which provides evidence for the claim that the items assess a similar construct. Wilcoxon analyses were computed between the different types of tasks. All task types were found to be significantly different from one another except for types one and two. Subtasks 2b, c and d had not been developed so it was possible that youngsters were able to solve Type 2 tasks perceptually without regard to discrete unit analysis. Multivariate analysis of variance revealed significant differences in task performance as a function of age ($F = 24.35$, $p < .001$) indicating the influence of developmental factors.

In a more recent study (Gamlin & Ash, 1987), the typology of tasks (excepting the

new subtasks 2c and d as well as all the new subtasks 3a, b, c, d and e) were given to forty-eight grade one and two children of mixed ethnic origin, mostly Japanese, Portugese and Vietnamese. Again, nonverbal instructions were followed by verbal prompts when necessary. No differences were found due to ethnicity, grade, or age. Verbal prompts, as for the Korean study, were found to substantially improve children's performance. Kendall's tau analysis indicated that Type 1 results correlated significantly with performance on types 2 and 4a tasks. Type 2 and Type 3 results correlated significantly with performance on type 4a tasks. And type 4a results correlated significantly with performance on type 4b tasks. Also, the correlations between Type 1 and Type 4b and Type 2 and Type 4b approached significance. This interrelatedness of the Typology of Tasks is shown in the coefficient alpha which was .66. Type 3 items produced very large individual differences within the group of forty-eight children, only two of whom were older than seven. We suspect that these items varied too greatly in difficulty level. When Type 3 items were removed from the Hoyt's analysis, the alpha increased to .75. The results from both studies suggest very strongly that a common underlying construct unites the typology of tasks.

A further analysis was performed on the most recent data. Since there were problems with the design of the Type 3 tasks, which were due to the varying difficulty levels of those tasks, pass/fail grades were assigned to the remaining typology of tasks without regard to Type 3 scores. Children scoring above seventy per cent on a particular type of task were assigned a passing grade for that type. A passing level above seventy would assign too many of the children a failing grade on the later Types, whereas a passing grade much less than that would not substantially alter the pattern of results obtained with a cut-off set at seventy. If the earlier Types of thinking are prerequisite, then children should not receive a passing score on later Types of tasks unless they have passed the earlier Types. Table 1 shows the results of this analysis.

Table 1
Pattern of results from pass/fail transformation

	TYPE	TYPE	TYPE	TYPE	FREQUENCY	
	F	F	F	F	6	
	P	F	F	F	11	
	P	F	P	F	2	*
	P	F	P	P	1	*
	P	P	F	F	12	
	P	P	P	F	16	
TOTAL	42	28	16	1	48	

As can be seen from the table above, 45 of the 48 children displayed pass/fail patterns that were consistent with the hypothesis that earlier Types of thinking are prerequisite for solving higher order Types of tasks. Consequently, while a common construct unites the typology, there is a hierarchical relationship between simpler and higher order versions of the metaphor tasks that make up the typology. Quite possibly, performance across the hierarchy of Types is constrained by neurological development. Consequently, instructional approaches to the teaching of metaphorical thinking must take development into consideration. One final observation concerns Type 4b performance. Approximately ten to fifteen youngsters most of whom were six years of age were able to understand most of the metaphoric analogies and were able to articulate the rules relating the terms in the analogies without receiving any help at all. With minimal instruction, some twenty to twenty-five youngsters were successful for most of these Type 4b tasks and were able to articulate the basis for the relationships across the various terms.

Implications and Conclusions

On the basis of the conceptual analysis and the foregoing results, we are able to state with increasing assurance that the hierarchy of types of tasks does indeed

constitute a developmental scale. Of course, construct validation studies must proceed to consider the new subtasks in Types 2 and 3 as well as a broader range of youngsters from three to four through twelve years of age.

An instructional approach to teaching metaphorical thinking would seem to be eminently possible. Indeed, as mentioned above, Savron (1988) has shown that with minimal kinds of intervention, six-year-olds were able to demonstrate significant gains in the "zone" established by the developmental scale. With the development of socratic procedures, one should be able to demonstrate even more dramatic "gains"; not only within particular Types of metaphorical thinking but across Types.

Future research will consider the implication of the development of metaphorical thinking for classroom learning. I have suggested above that this kind of development is essential for the generalization of knowledge across mixed domains of tasks both at similar levels of complexity as well as at higher levels of complexity. I have argued that this is the case because the metacognitive activity implied in metaphorical thinking enables youngsters to consider new tasks with respect to knowledge and strategy that has been acquired through past experience. Consequently, with instruction in the "zone," youngsters should become more adept at pulling out the "gist" of reading passages that vary in the degree to which inferential thinking is required. To use the terminology of Brown & Smiley (1977), youngsters should become more proficient in identifying the most important "idea units" in reading passages as well as more proficient in ordering these ideas units from most to least important. With instruction in the "zone," youngsters should demonstrate significant gains in the way they go about summarizing these passages in writing. One would expect that the effects of increased metacognitive activity would be especially evident in the way youngsters attempt to put their ideas into writing. I have had some success showing that this is the case (see Gamlin, 1984).

Finally, one would like to explore the impact of individual differences; both with

respect to youngsters' ability to profit from instruction in the "zone" as well as in the application of metacognitive skills across mixed domains of tasks. I have suggested elsewhere (Gamlin, 1988) that the attitudes youngsters have acquired about themselves as competent or less than competent learners are directly responsible for not only the level of enthusiasm they bring to new learning situations but also the kinds of learning strategies that they bring to these situations. I am in complete agreement with Dweck's (1986) analysis of the relation between motivation and learning and the extremely important role of social cognition. Suffice to say here that there would appear to be a category of youngsters who learn for themselves, to improve their "personal best," while another category of youngsters seem to be oriented towards performing "for others." There are very real "strategic," learning style consequences for these different orientations. It may very well turn out to be the case that these kinds of attitudinal variables will determine to a considerable extent the degree to which individuals will want to restructure their knowledge. Consequently, the generalization of knowledge and degree of metaphoric activity may be severely influenced by the attitudes individuals hold about themselves as learners.

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Figure 1.

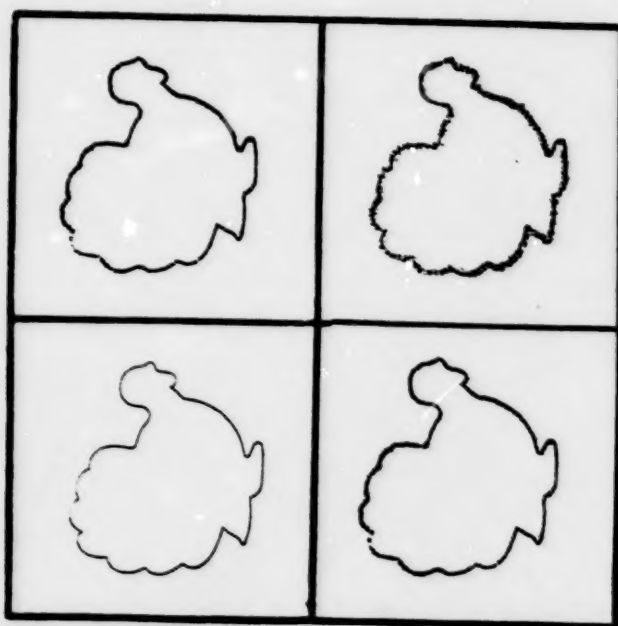


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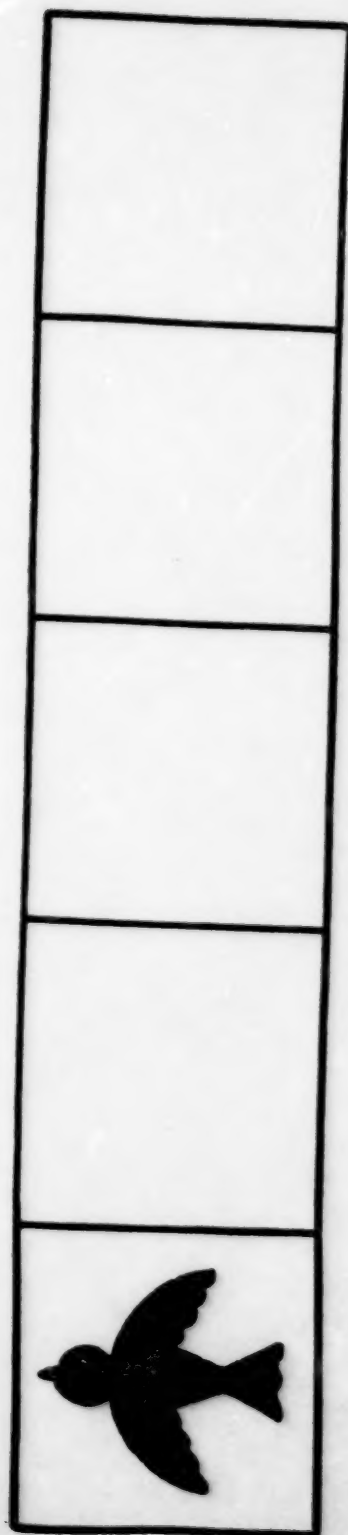
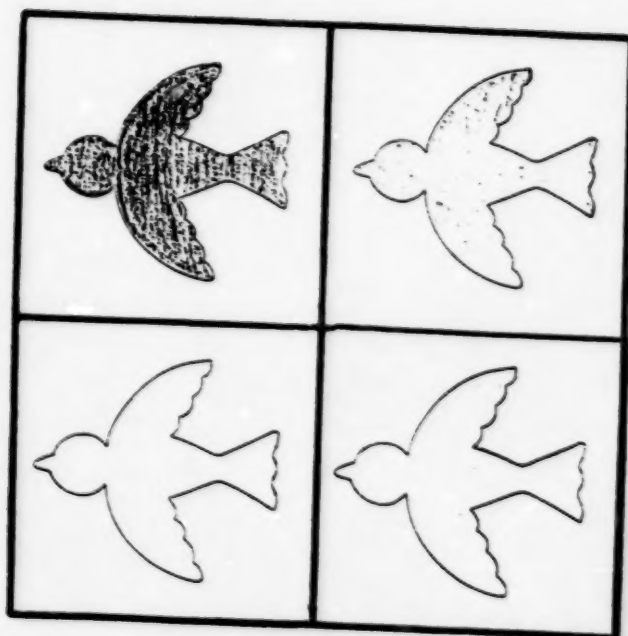


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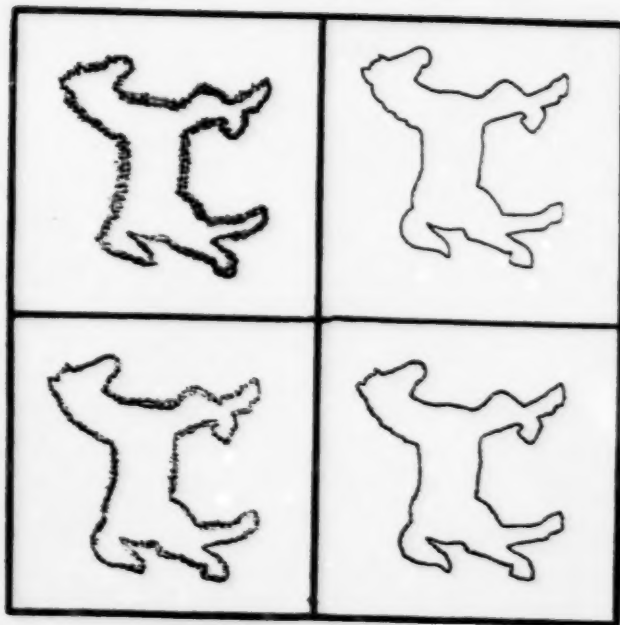


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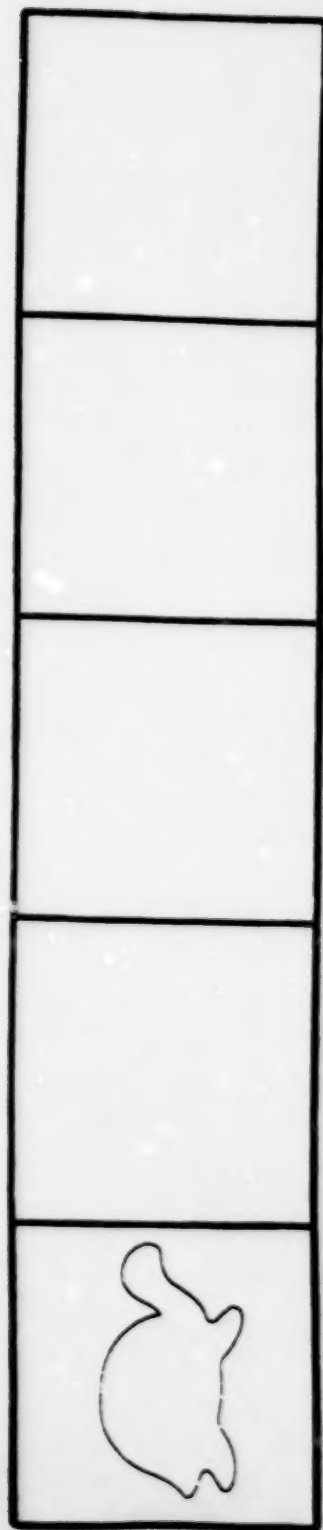
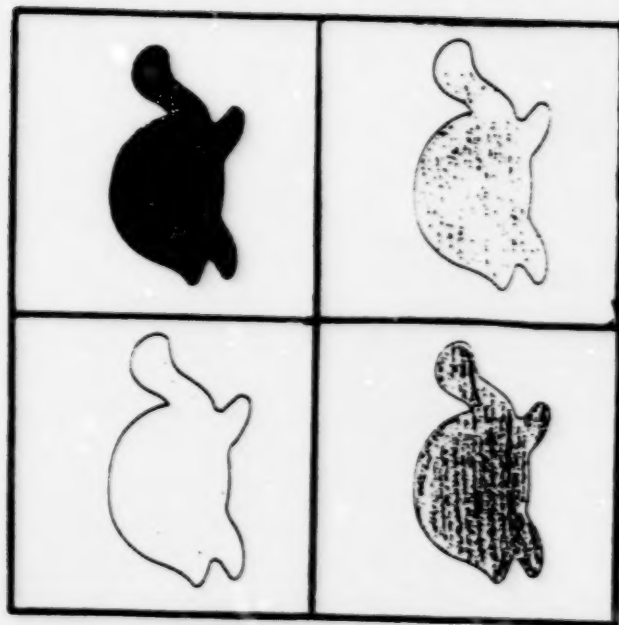


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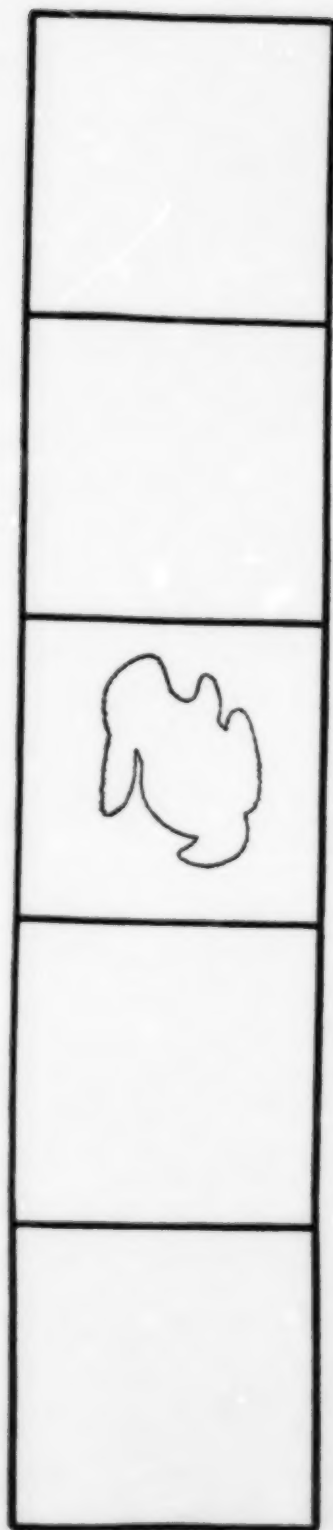
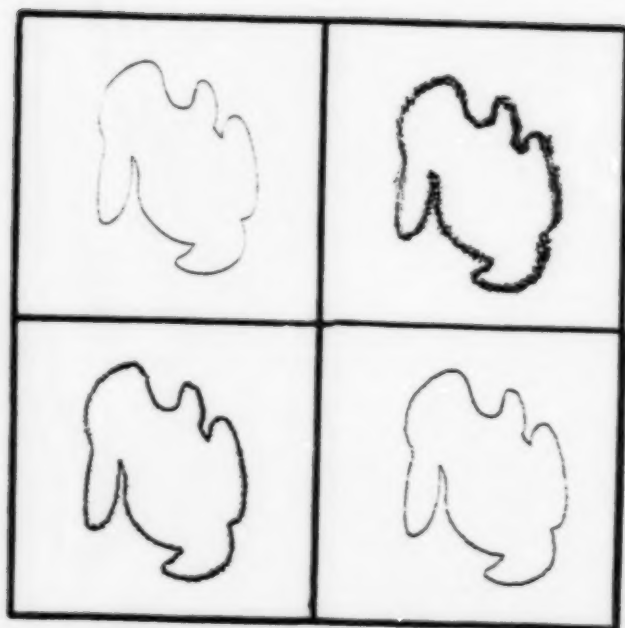


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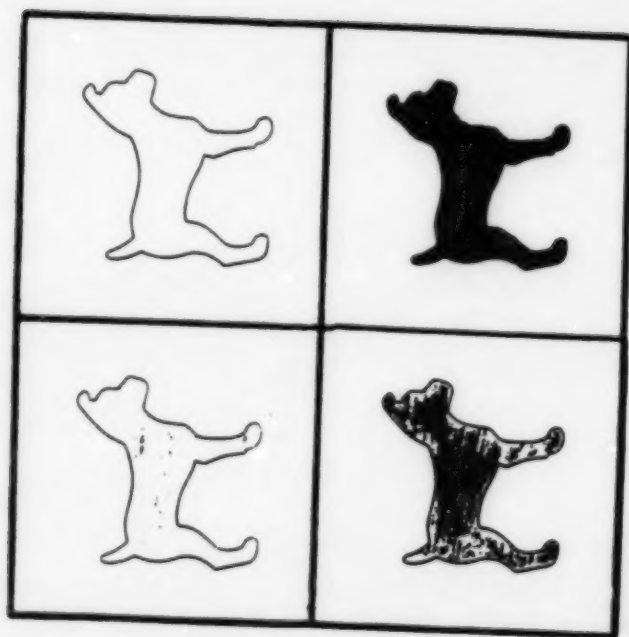


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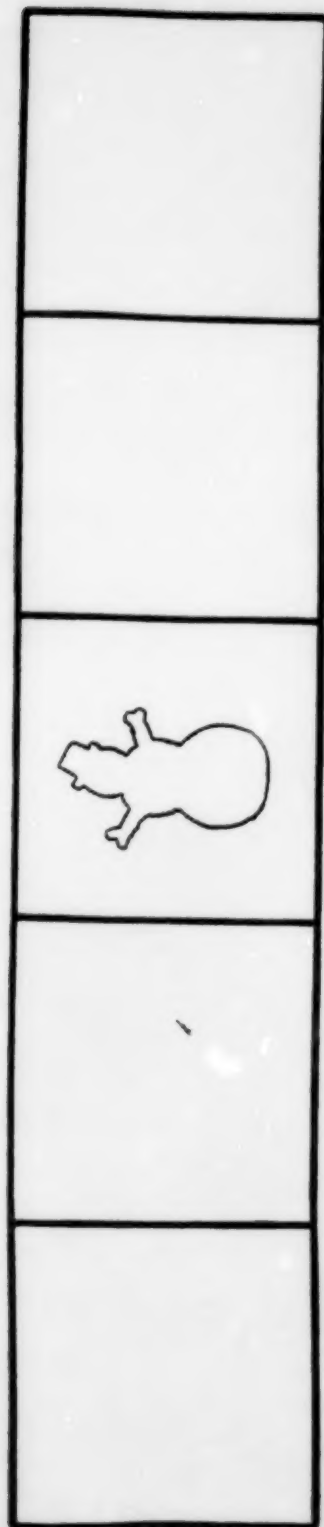
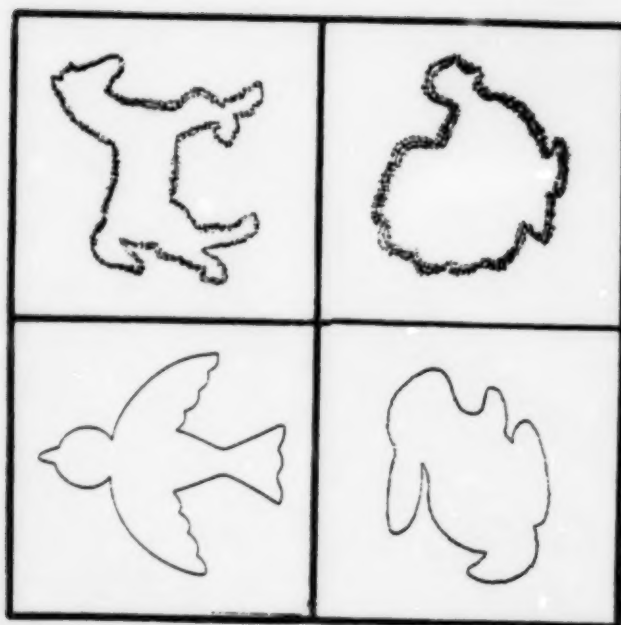


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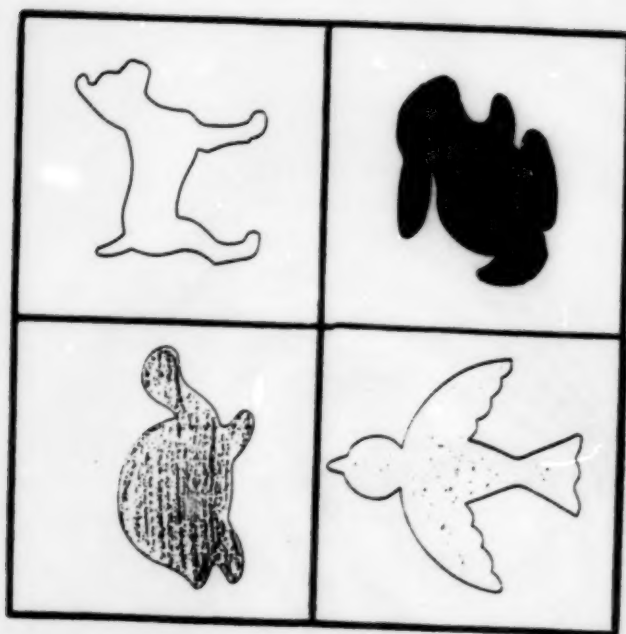


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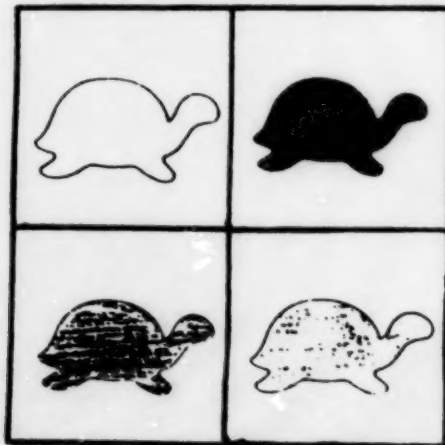
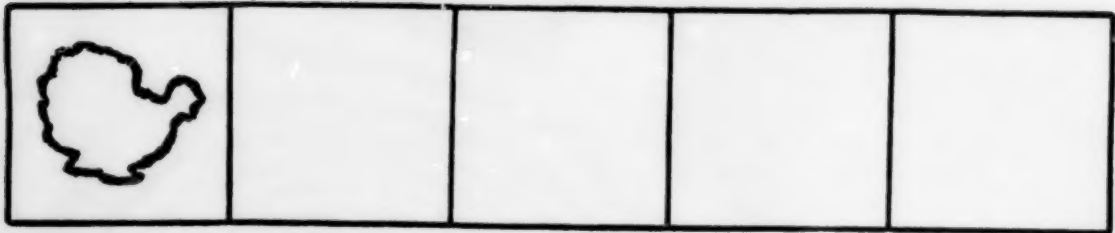
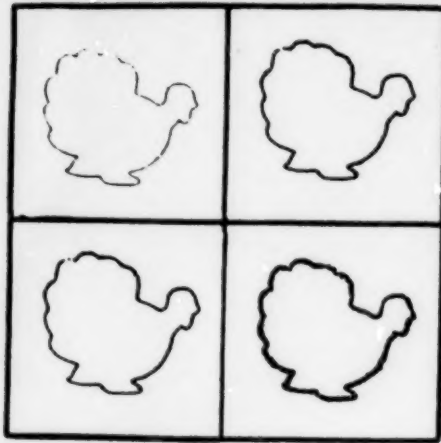


Figure 10.

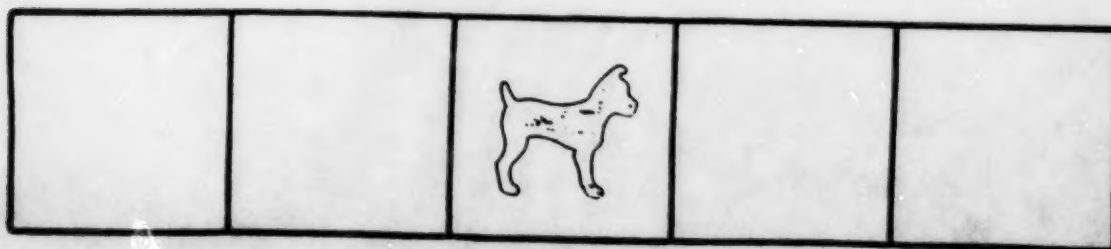
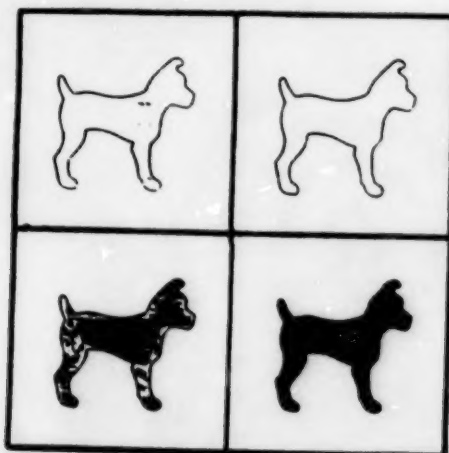
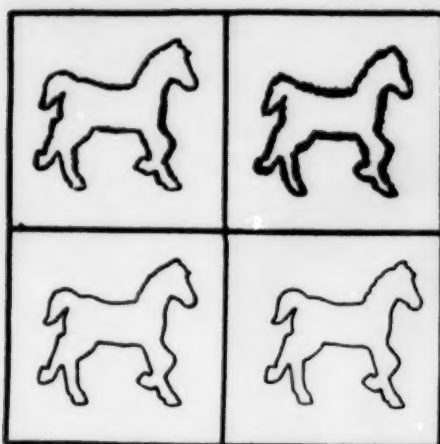


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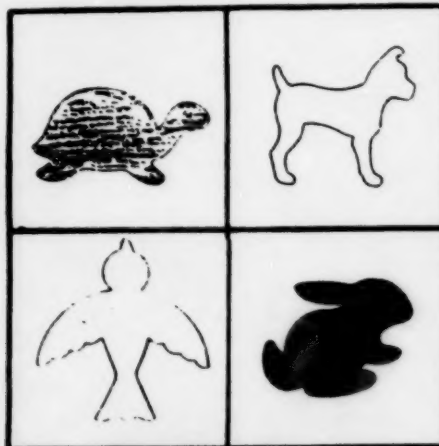
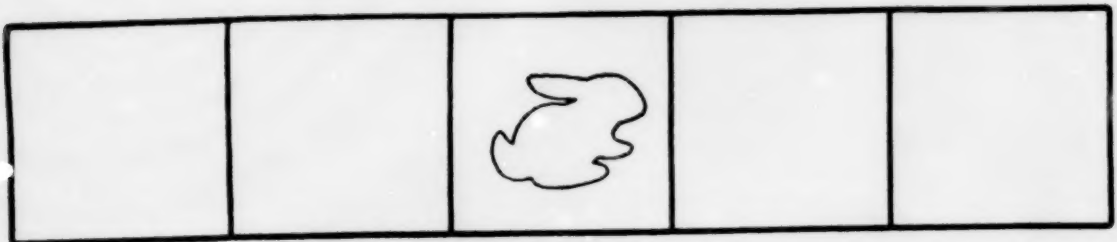
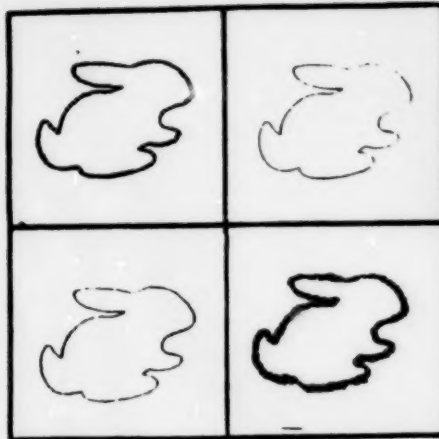


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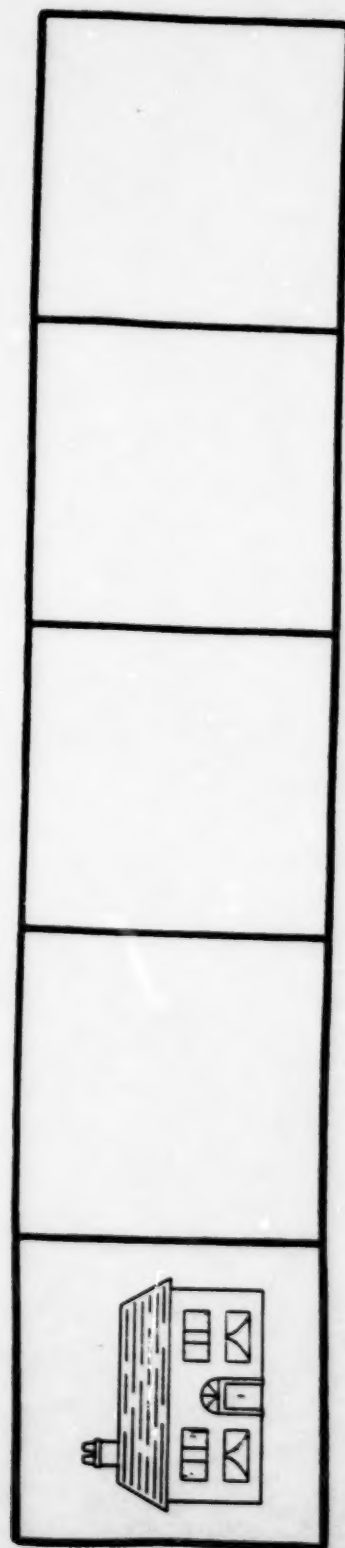
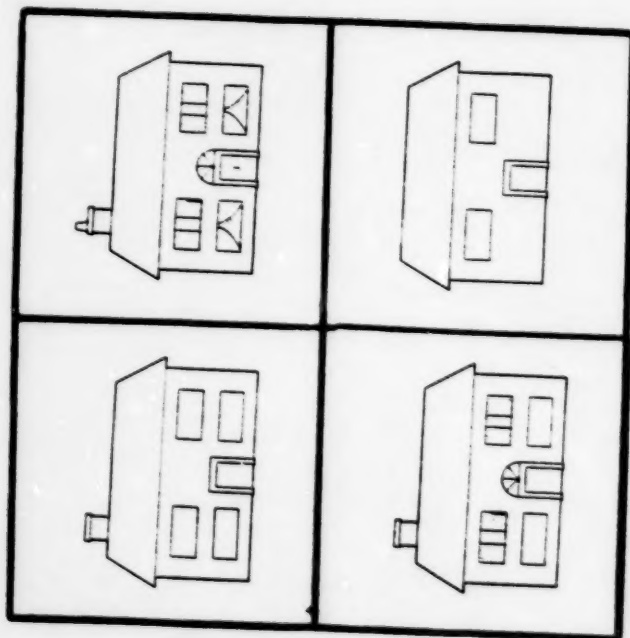


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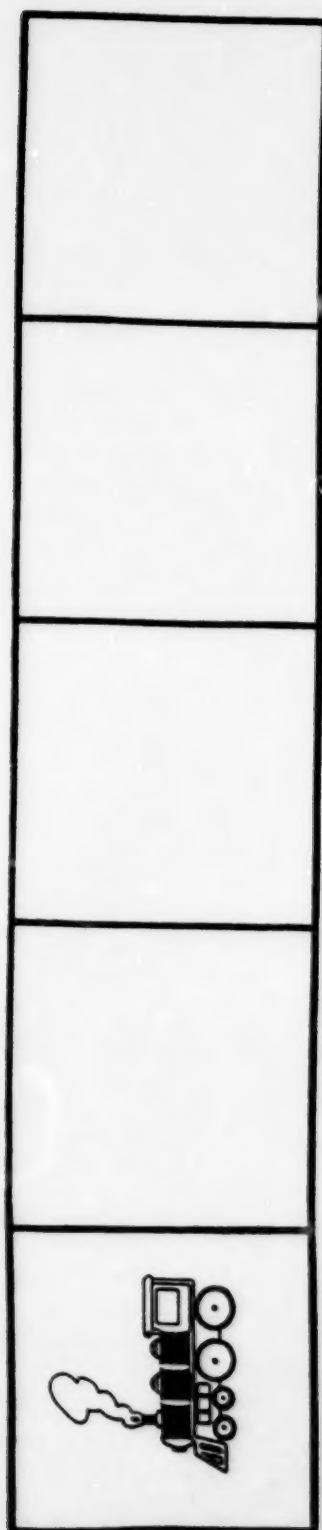
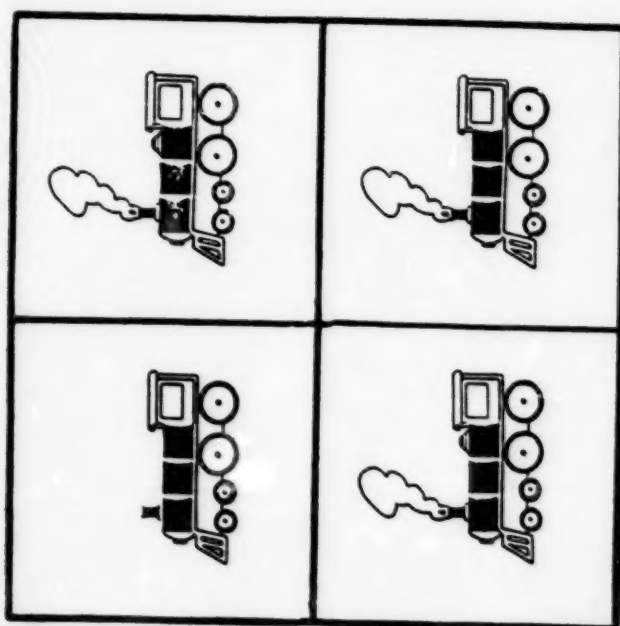


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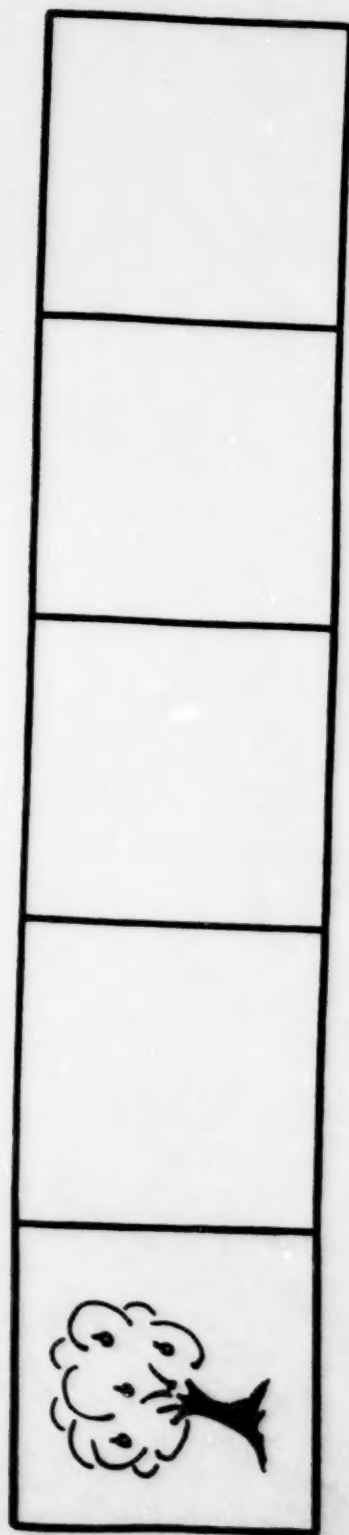
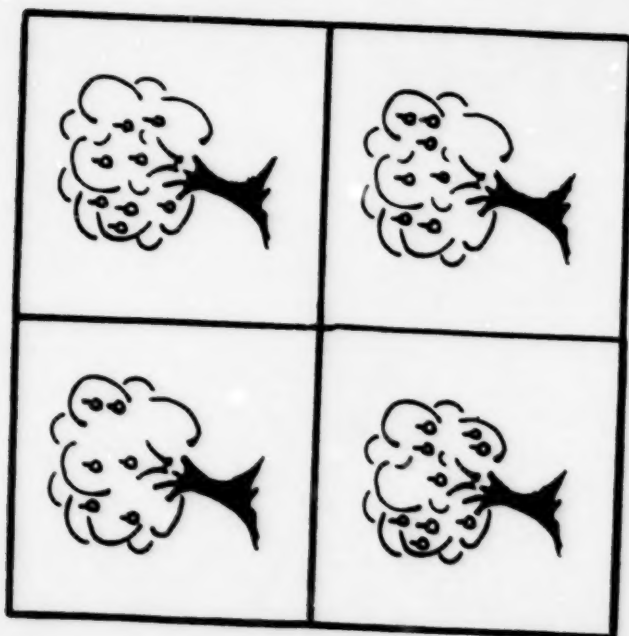


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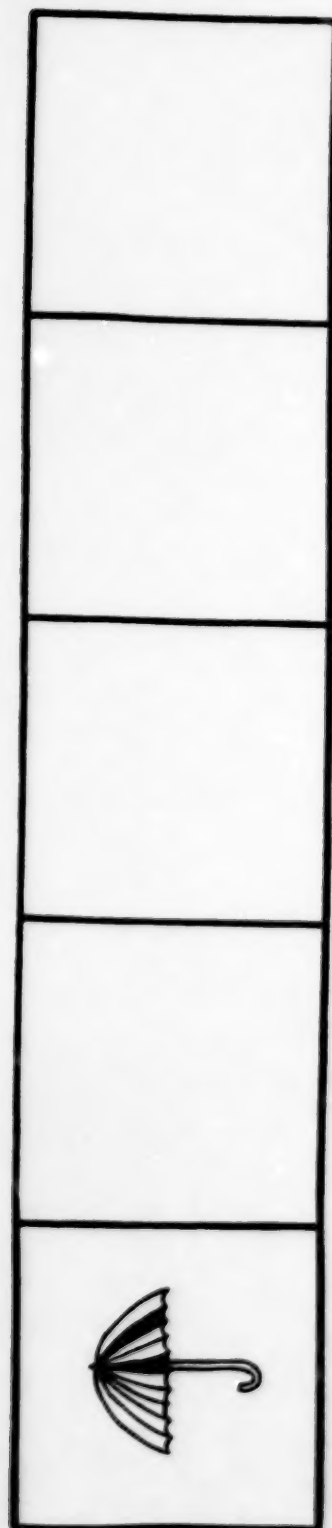
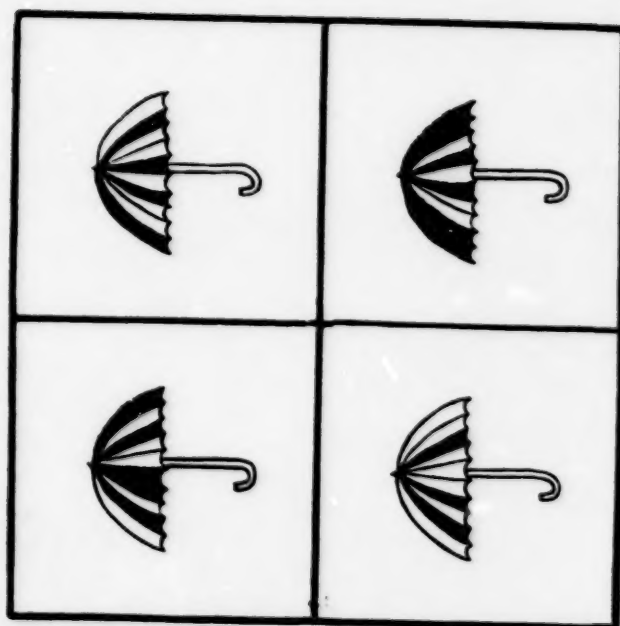


Figure 16.

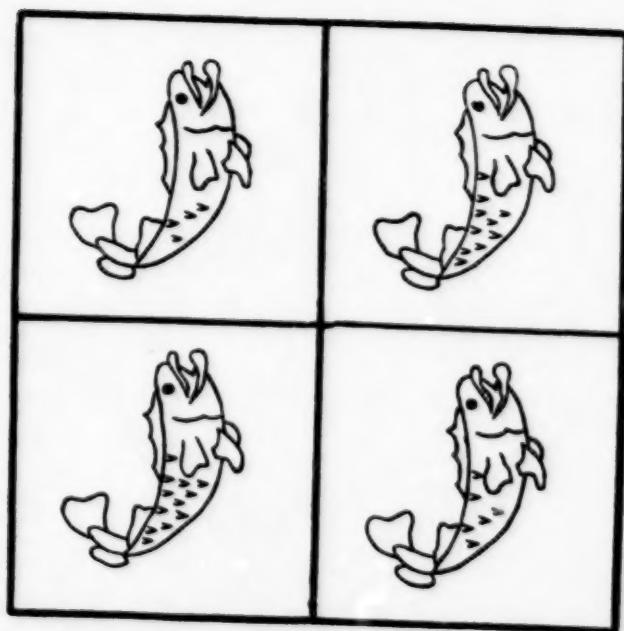


Figure 17.

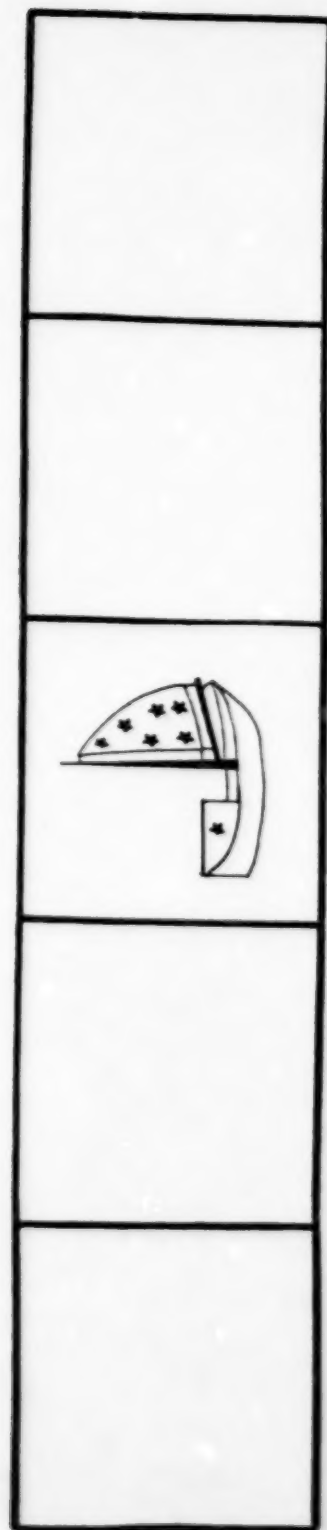
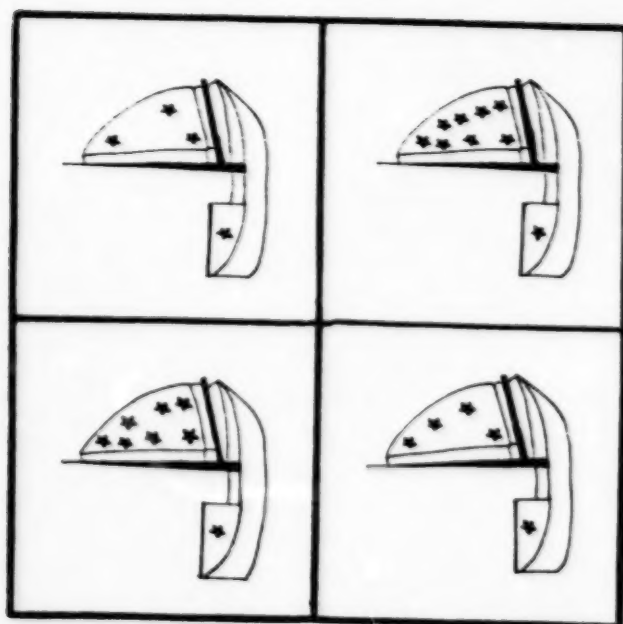


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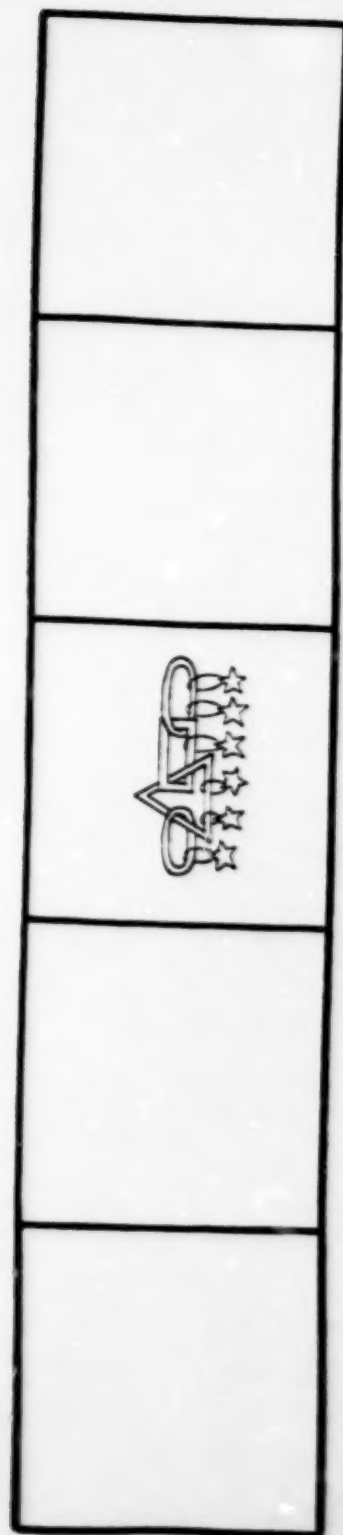
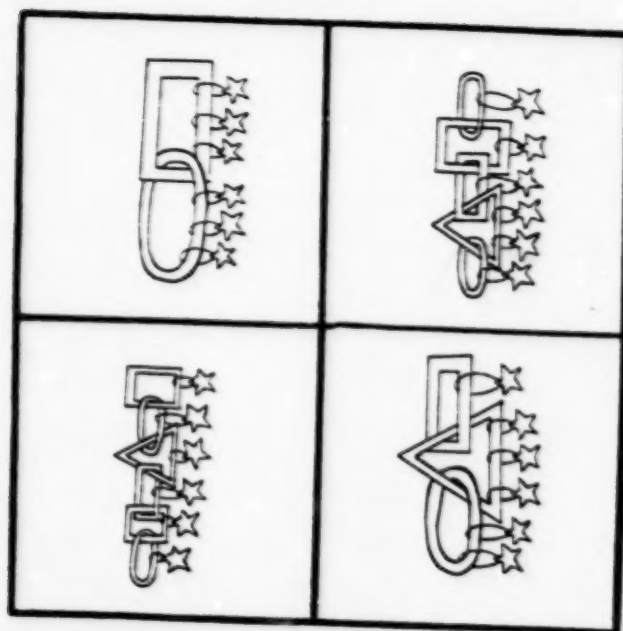


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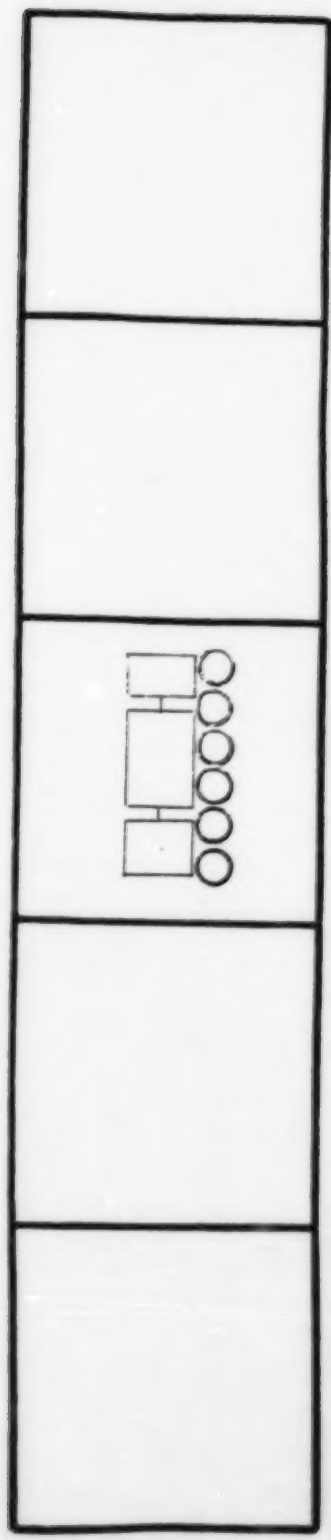
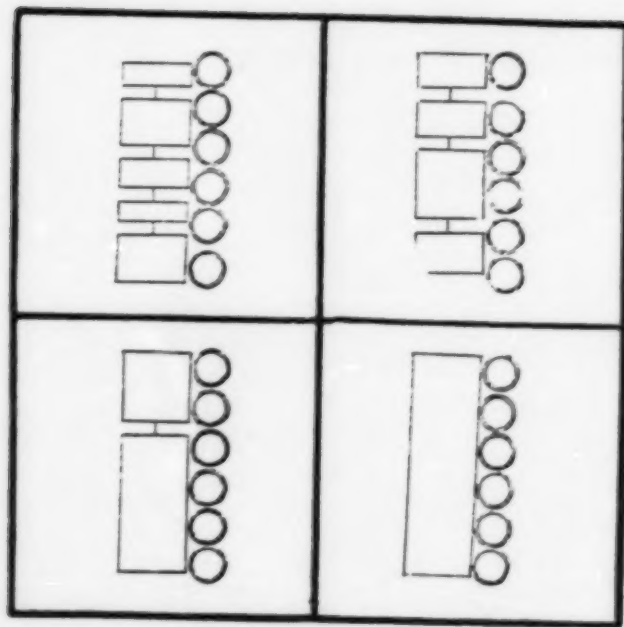


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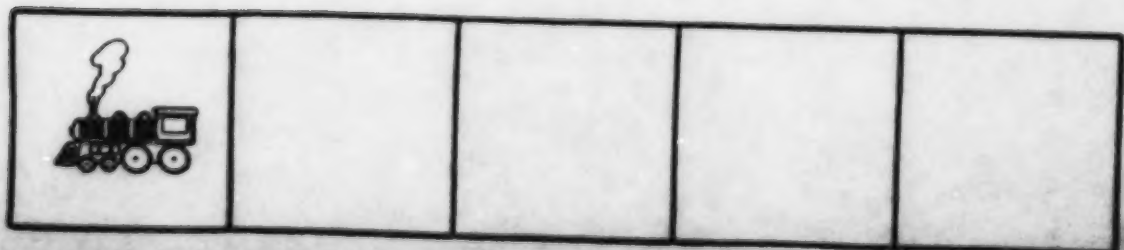
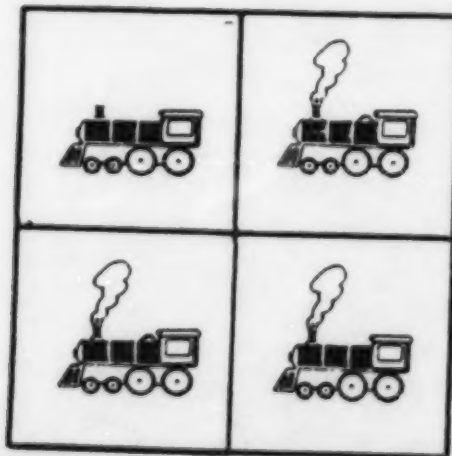
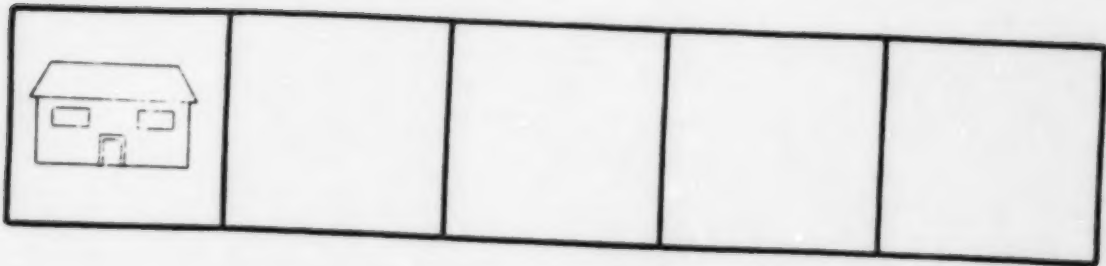
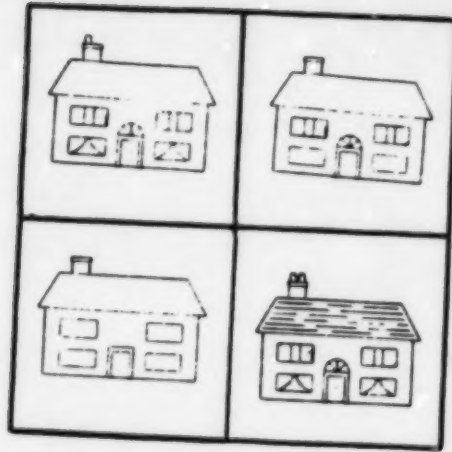


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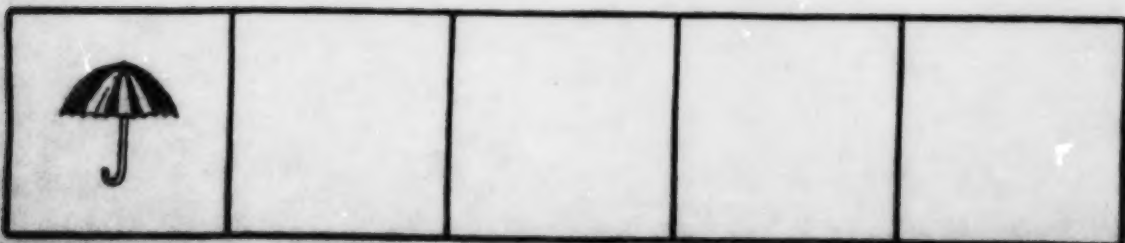
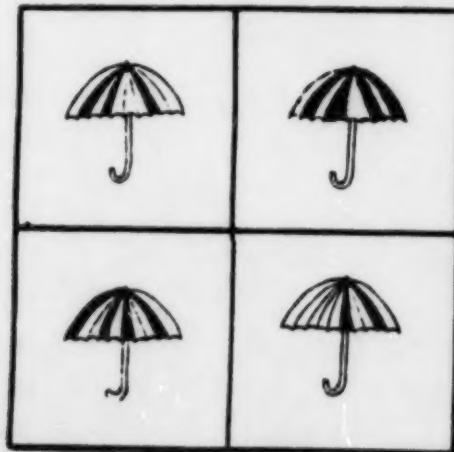
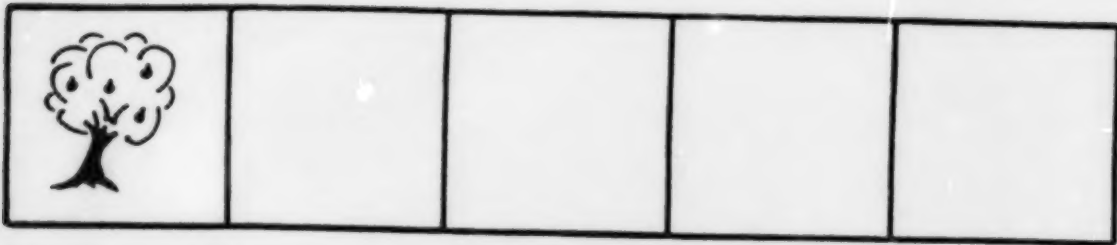
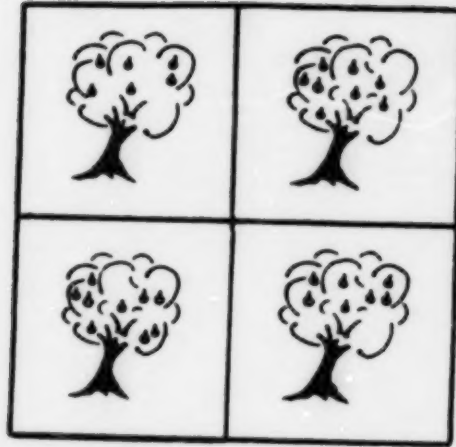


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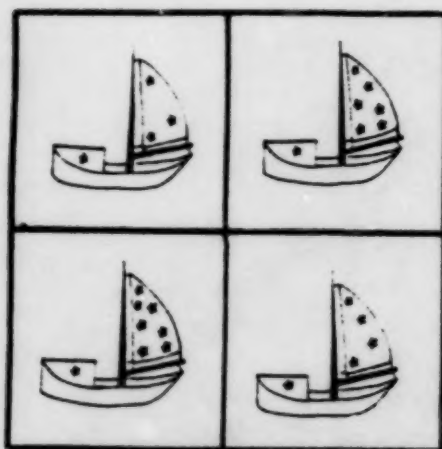
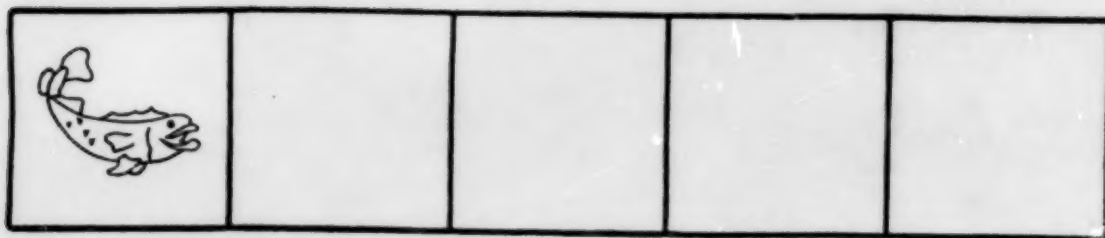
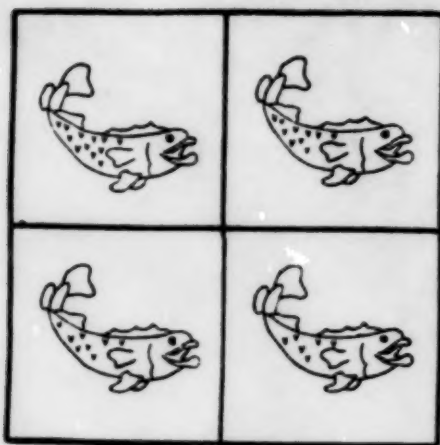


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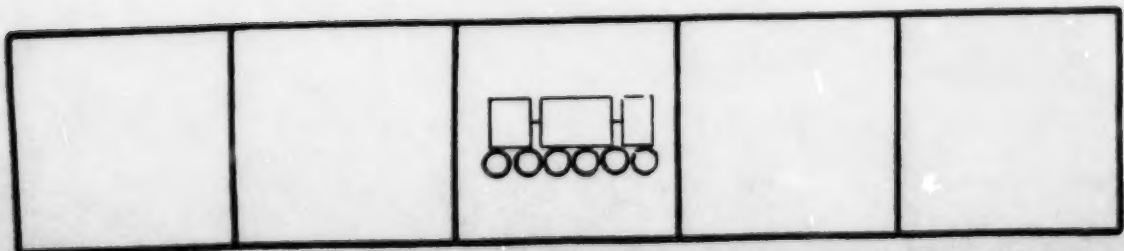
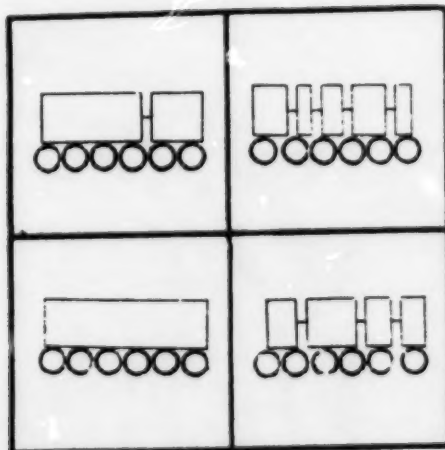
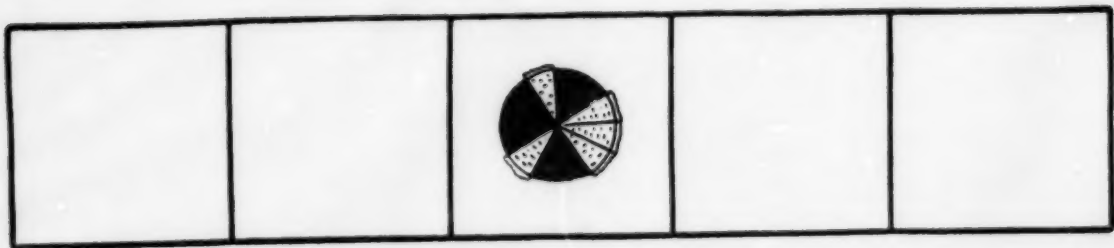
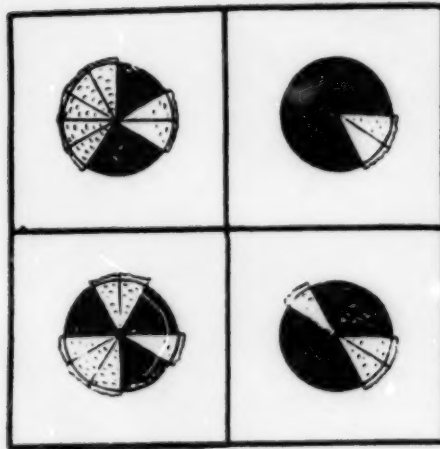


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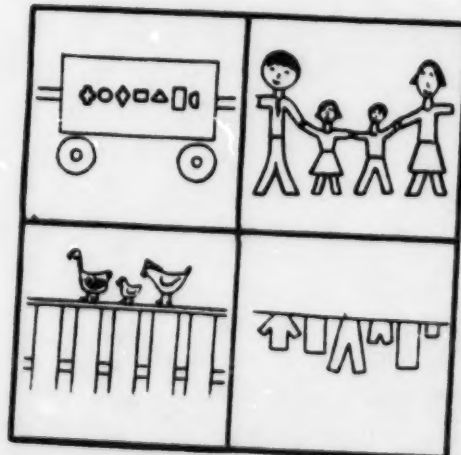
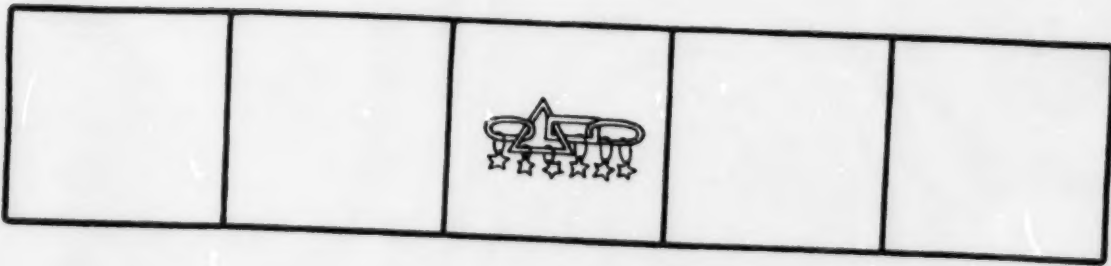
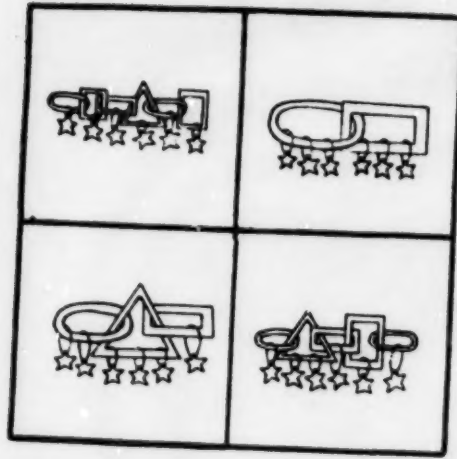


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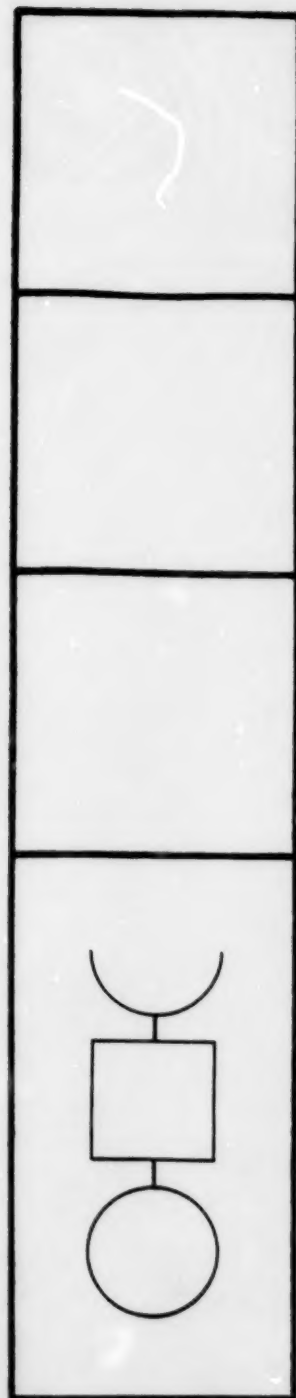
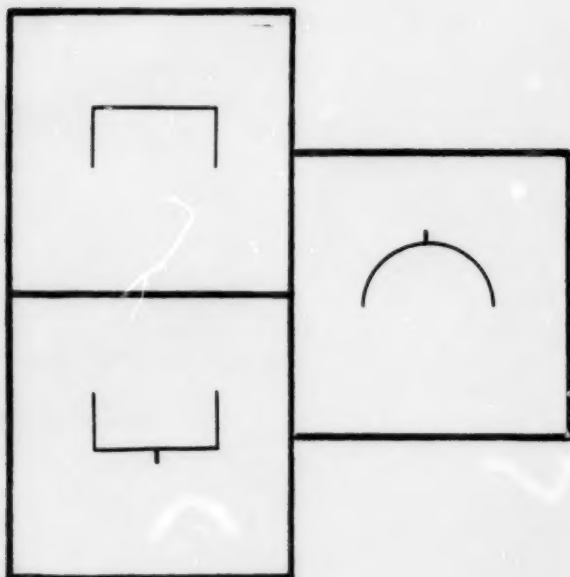


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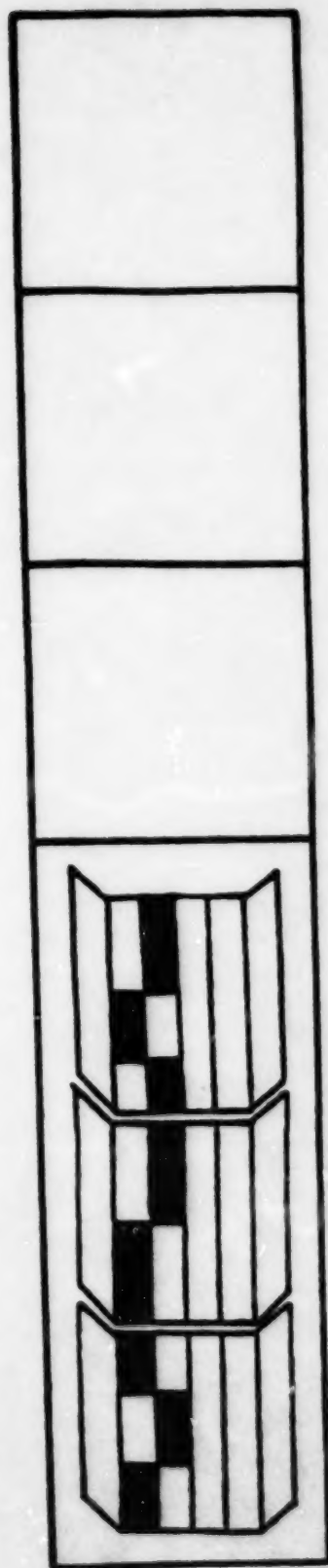
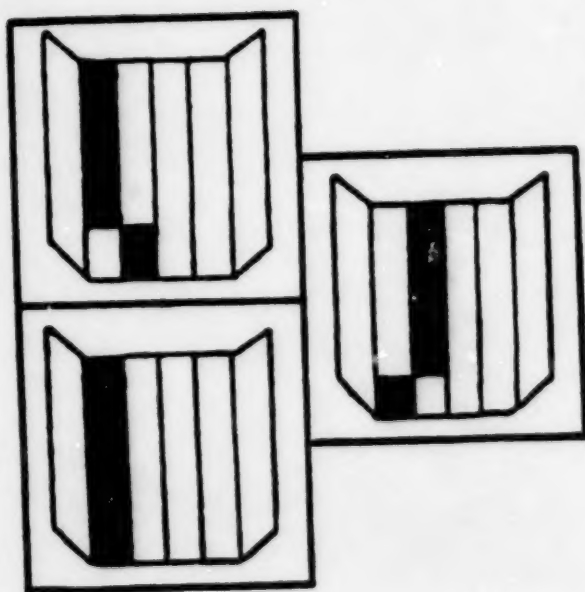


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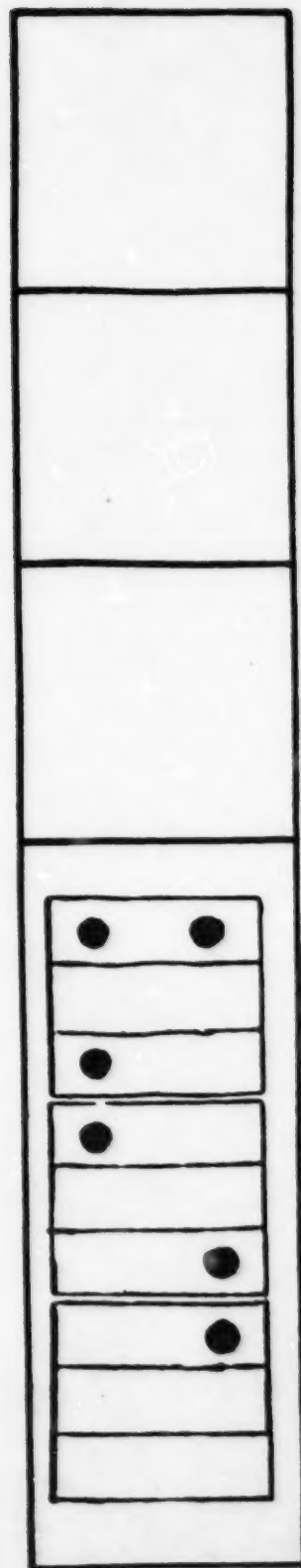
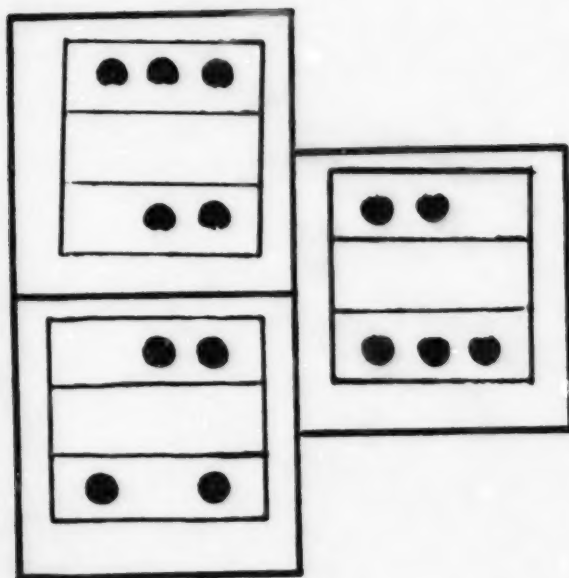


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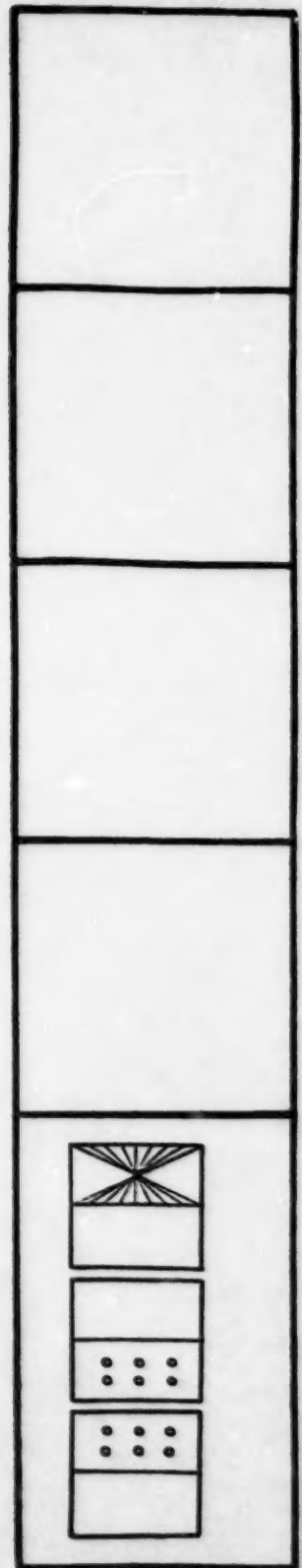
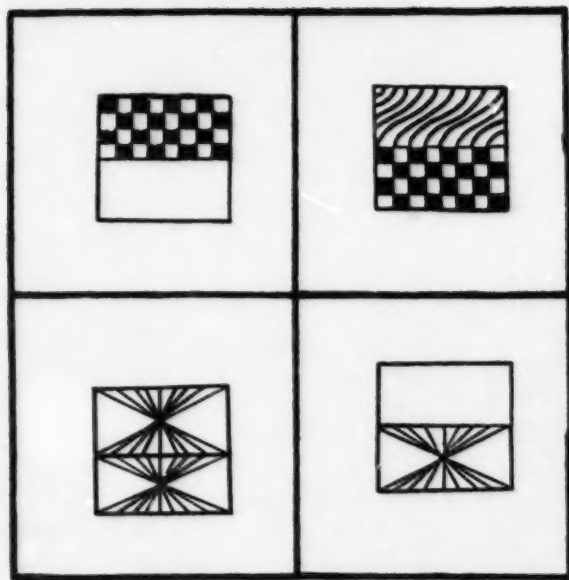


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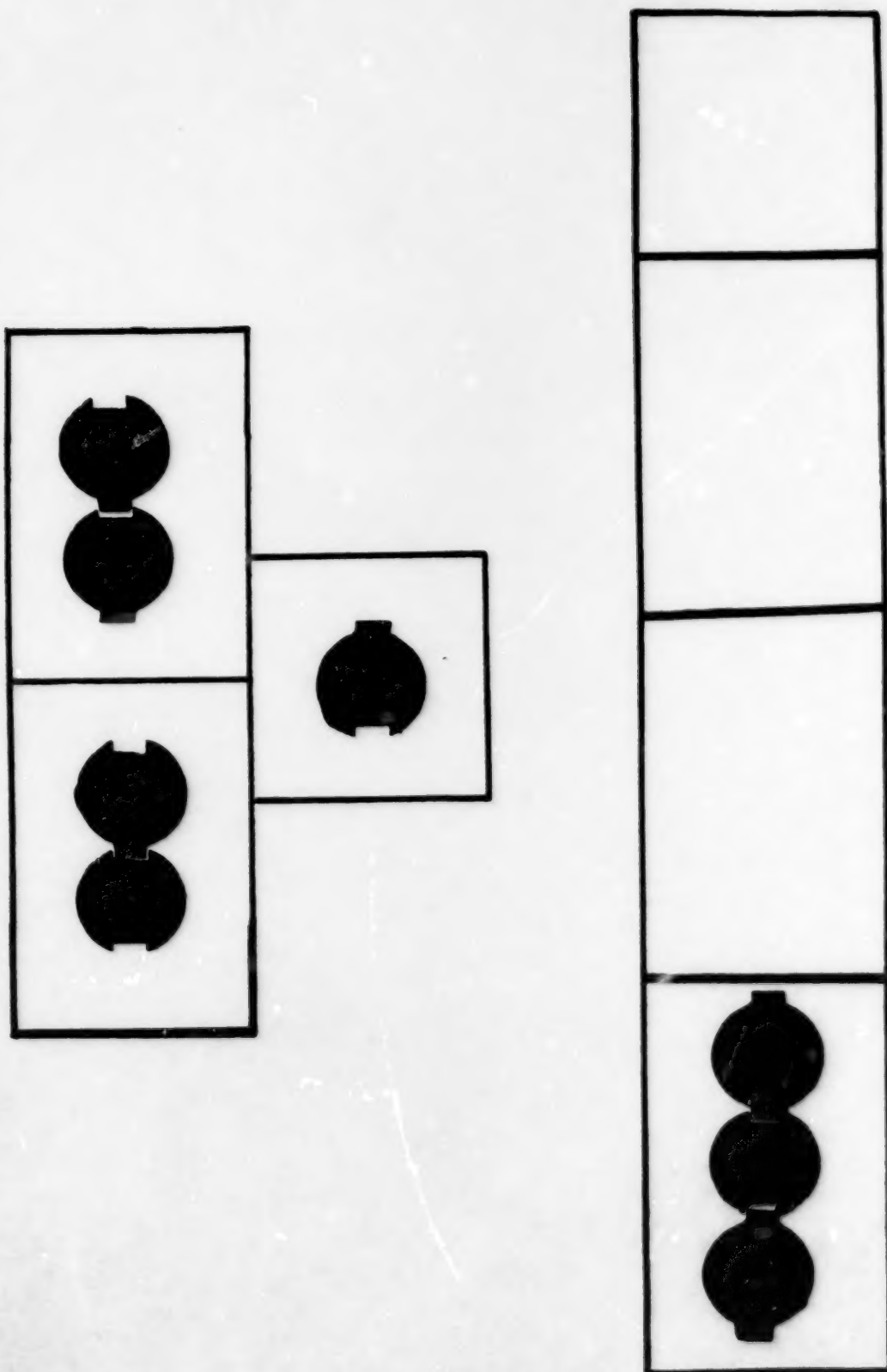


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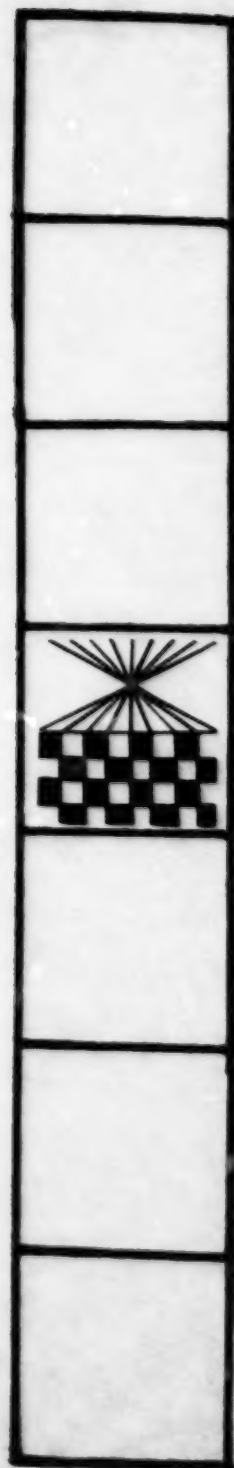
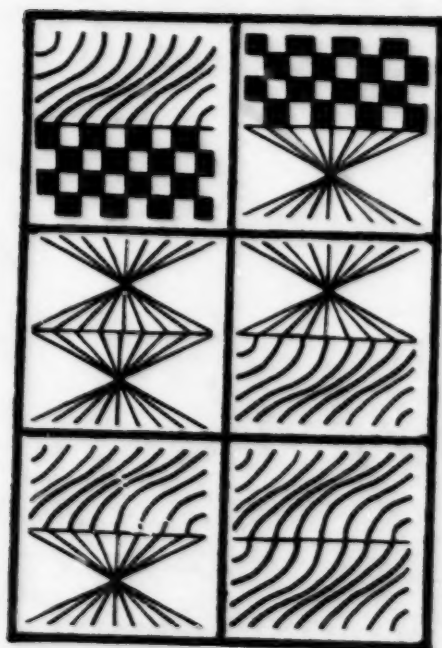


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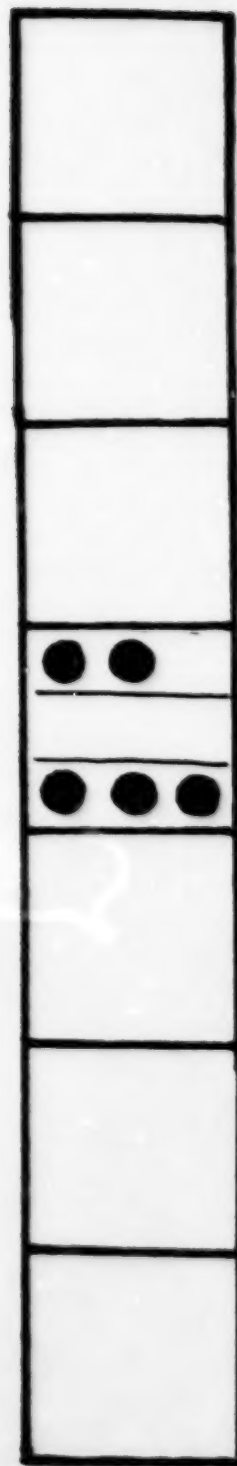
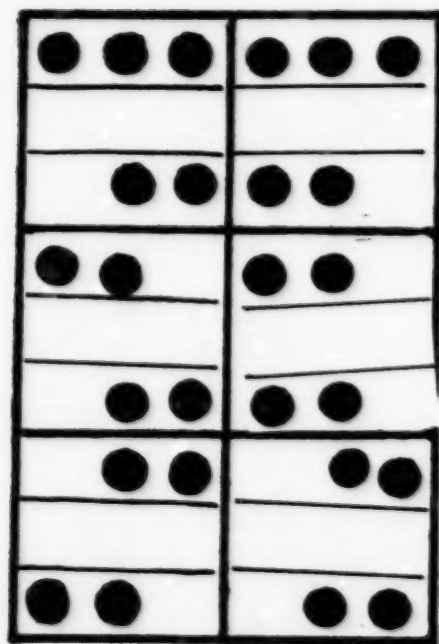


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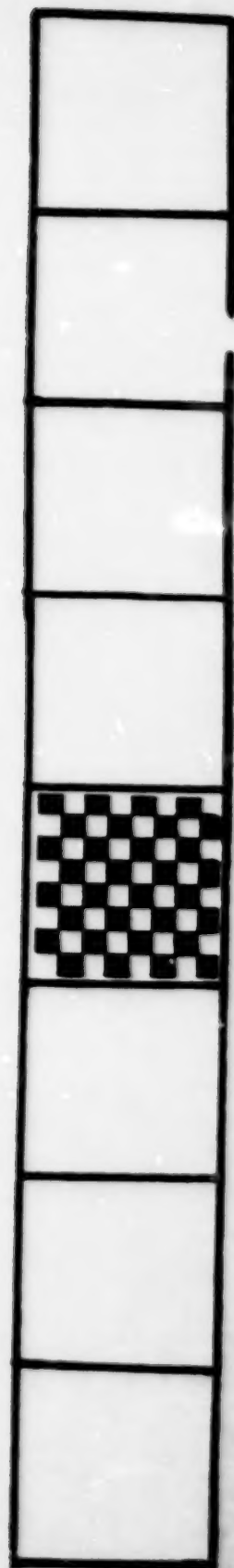
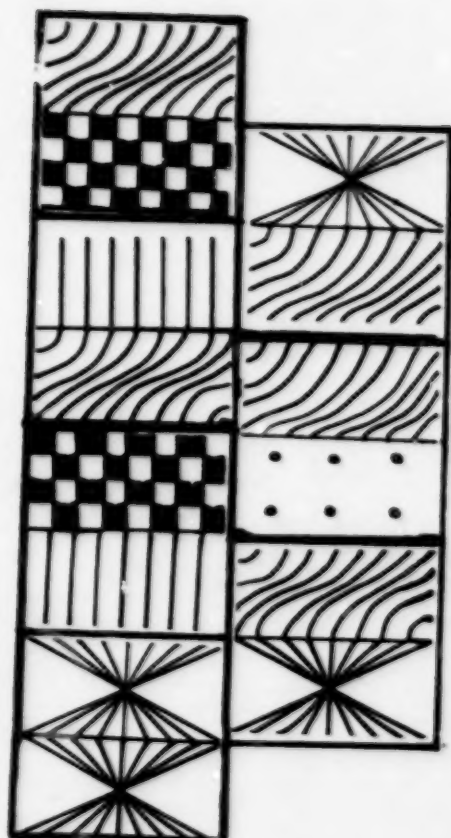
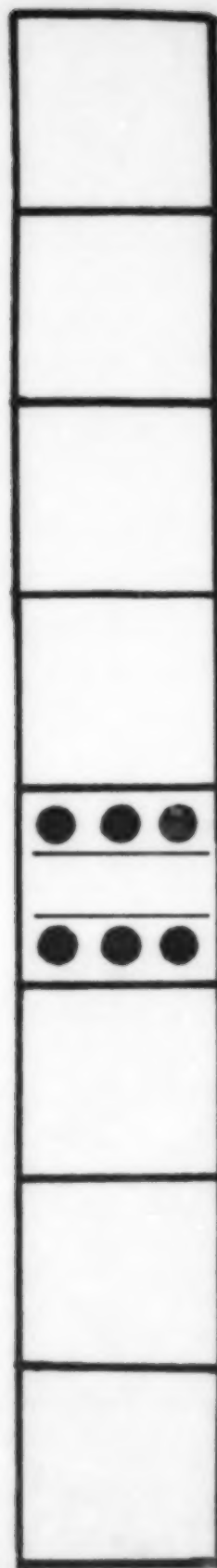
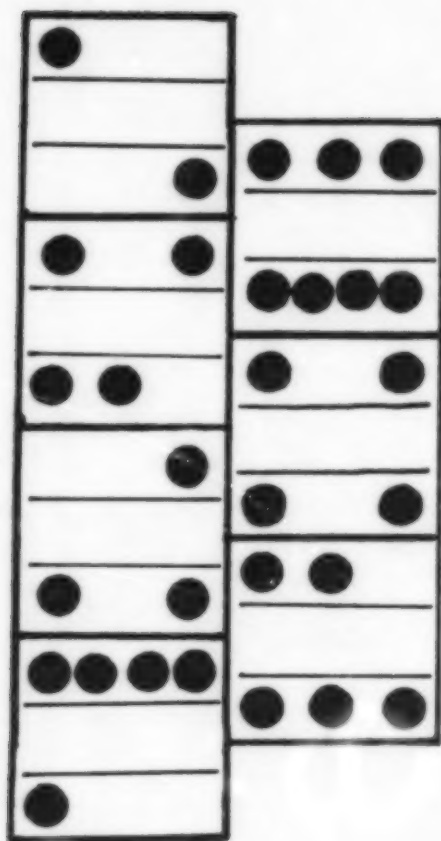


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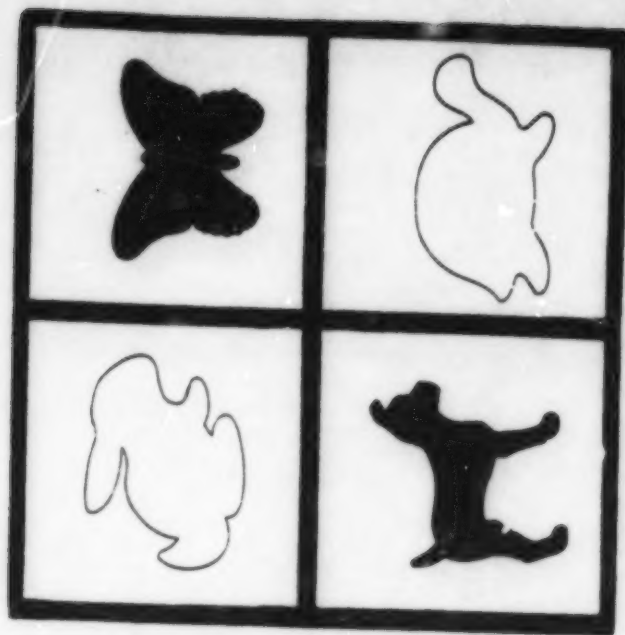


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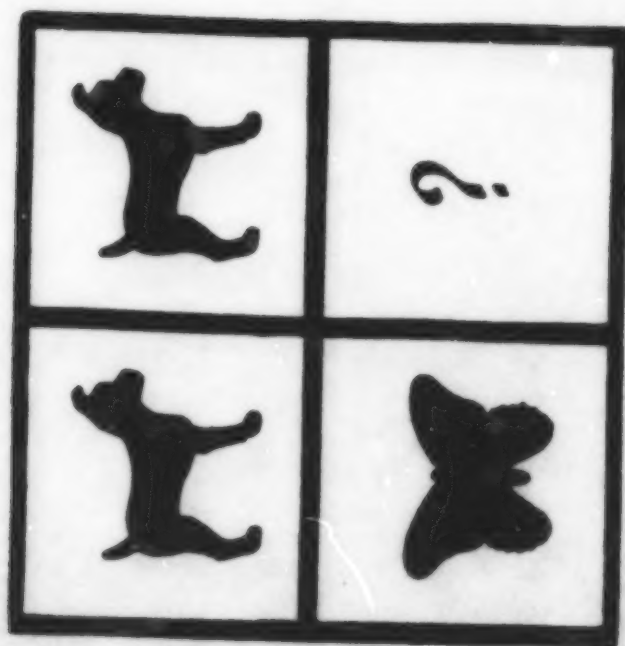
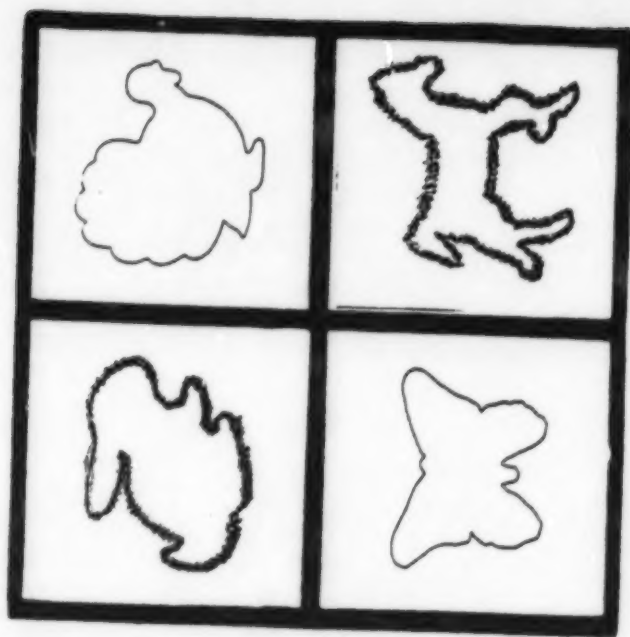
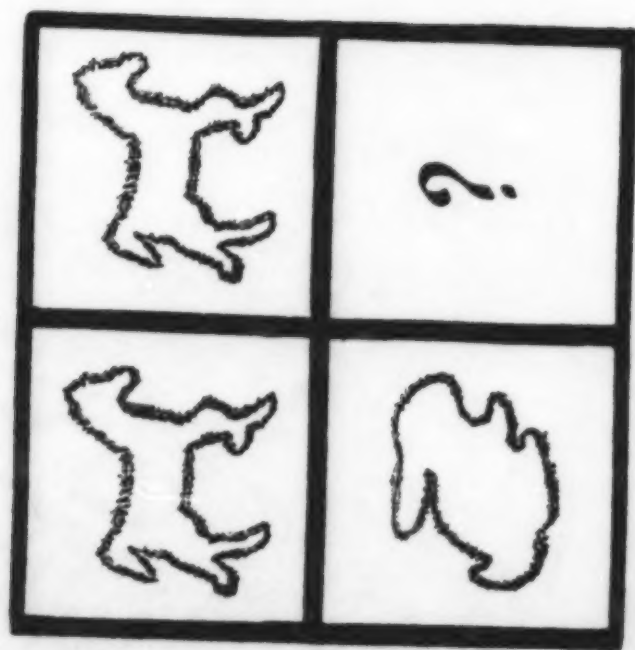


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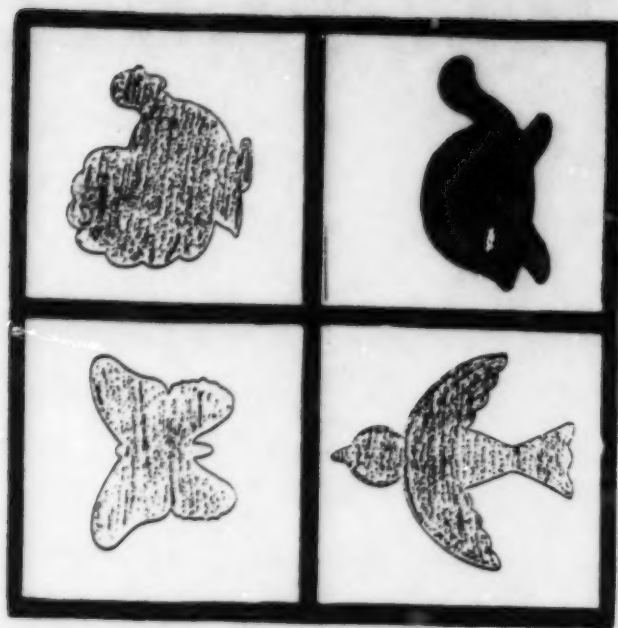


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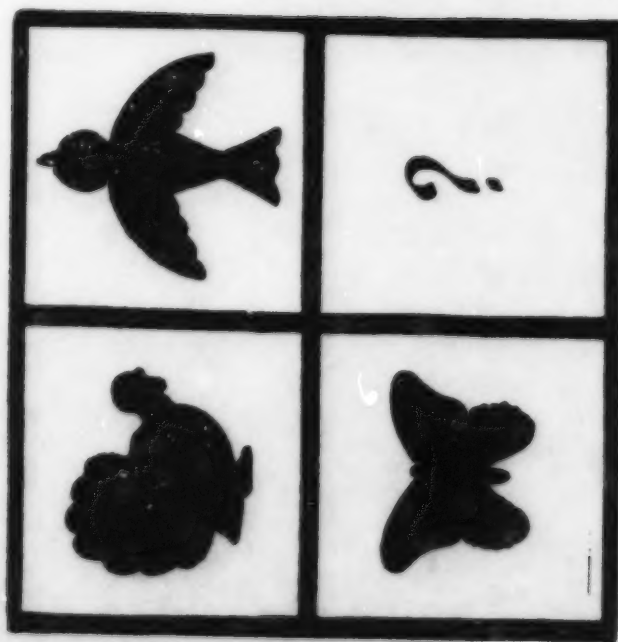


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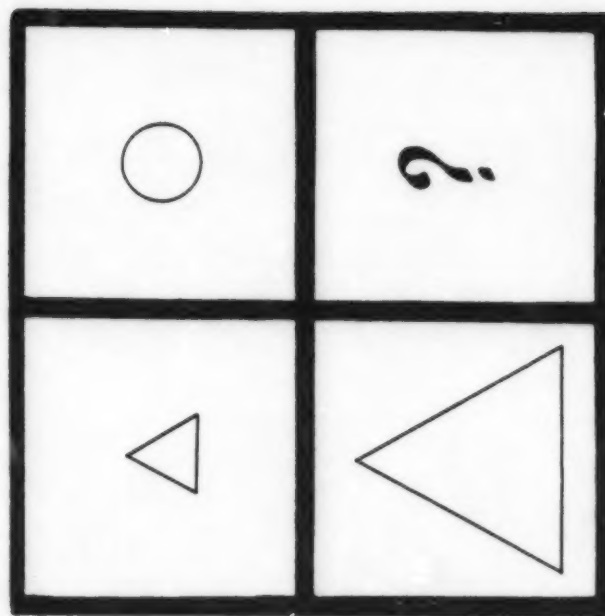
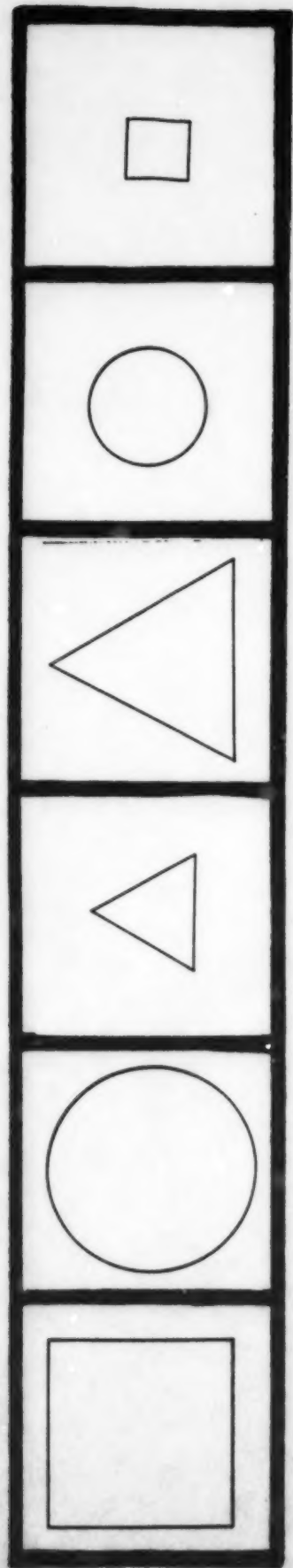


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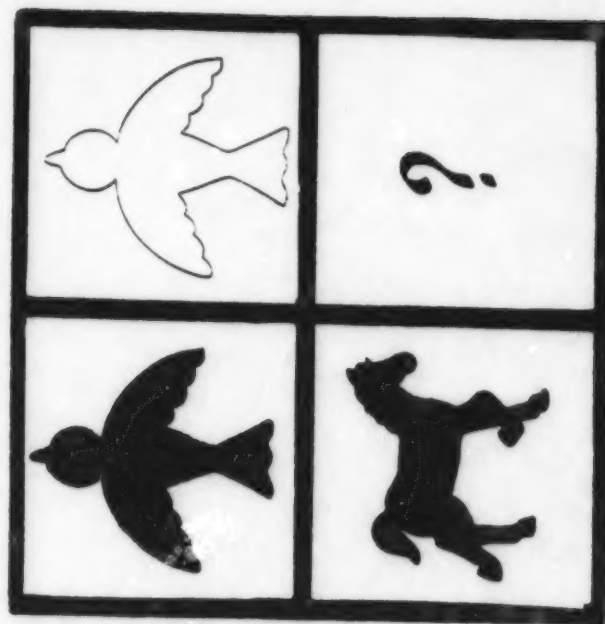
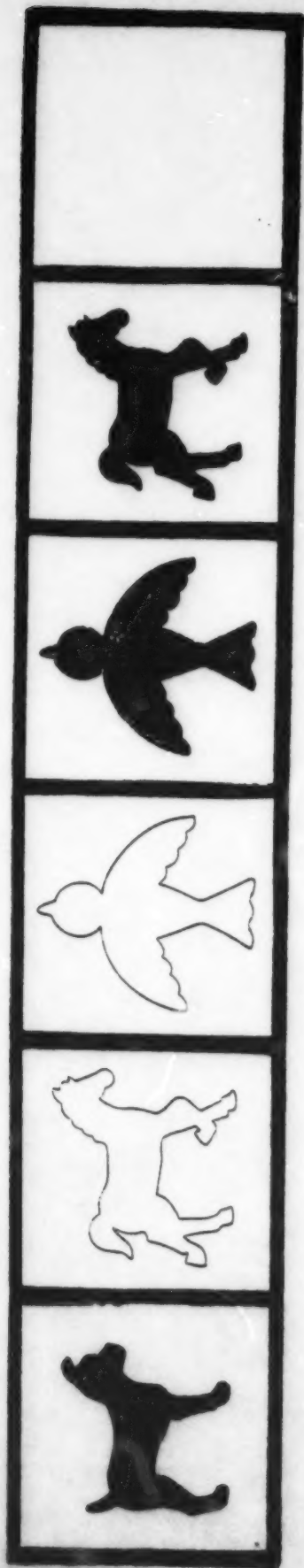


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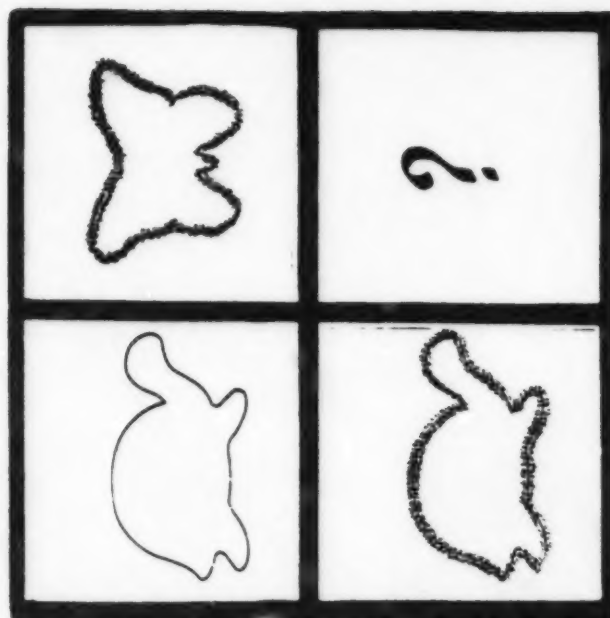
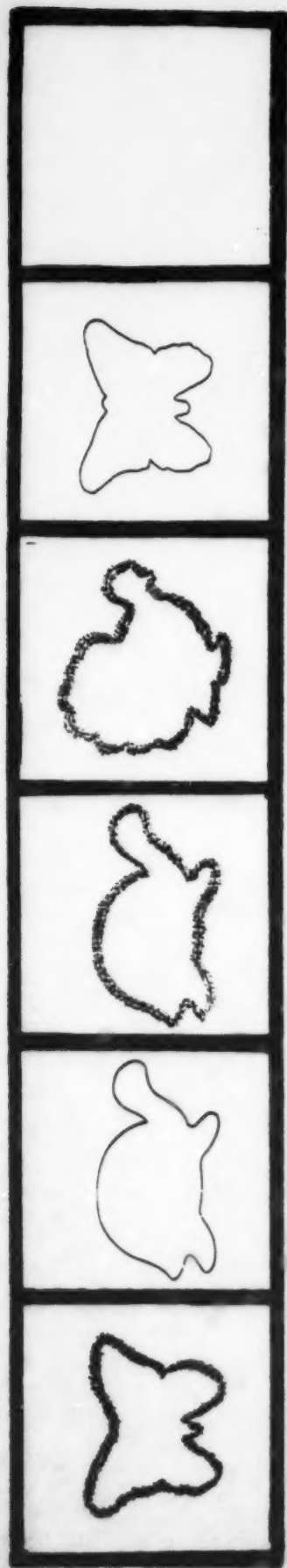


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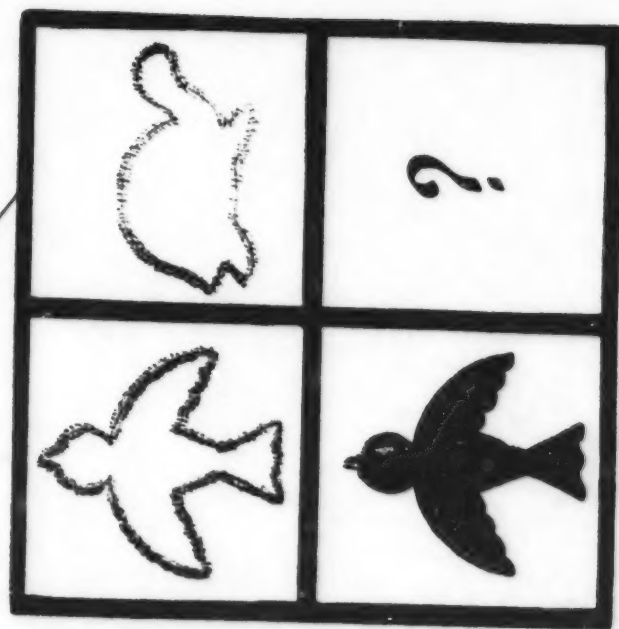
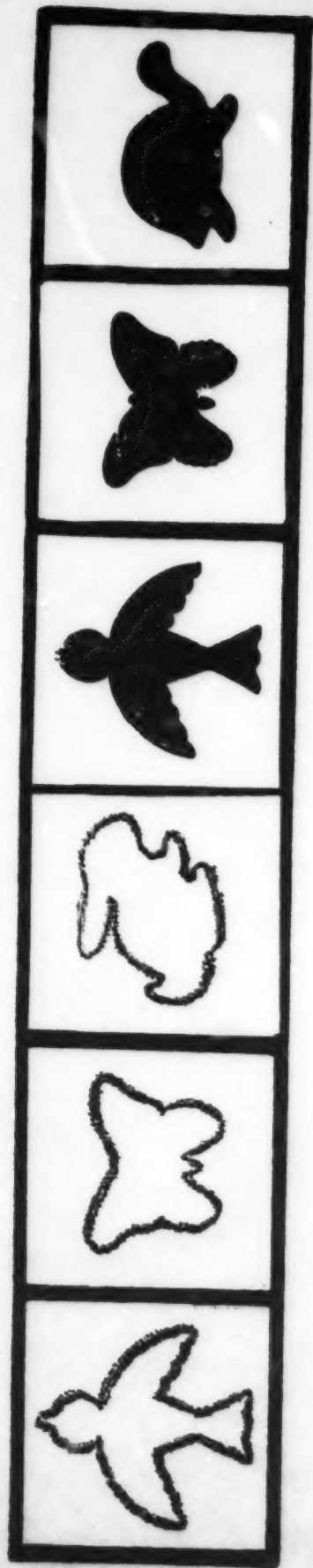


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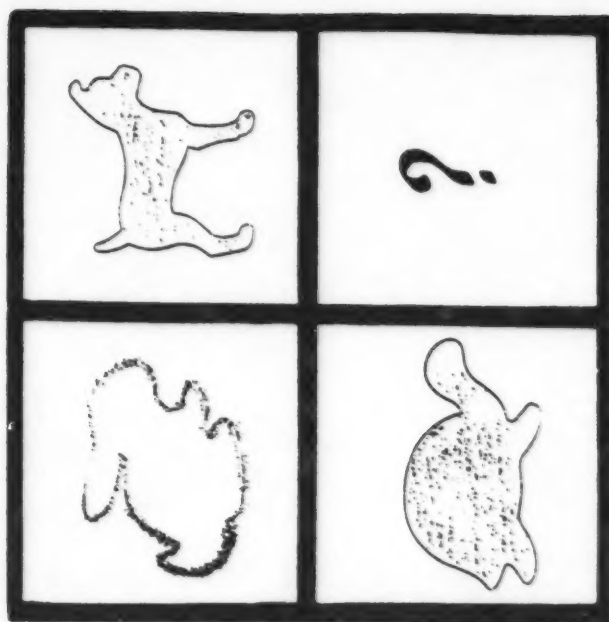
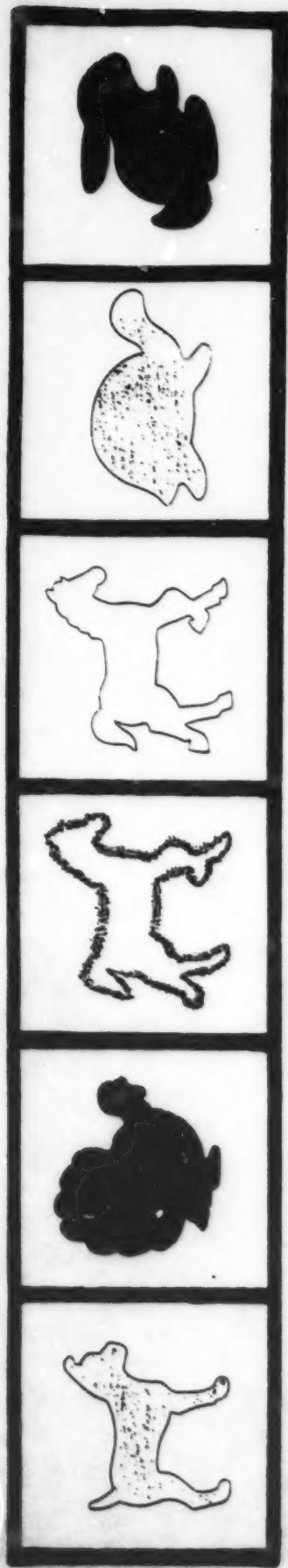


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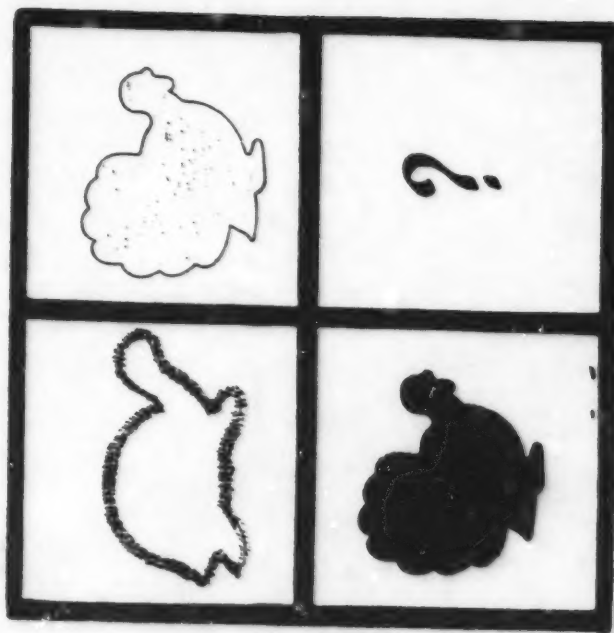
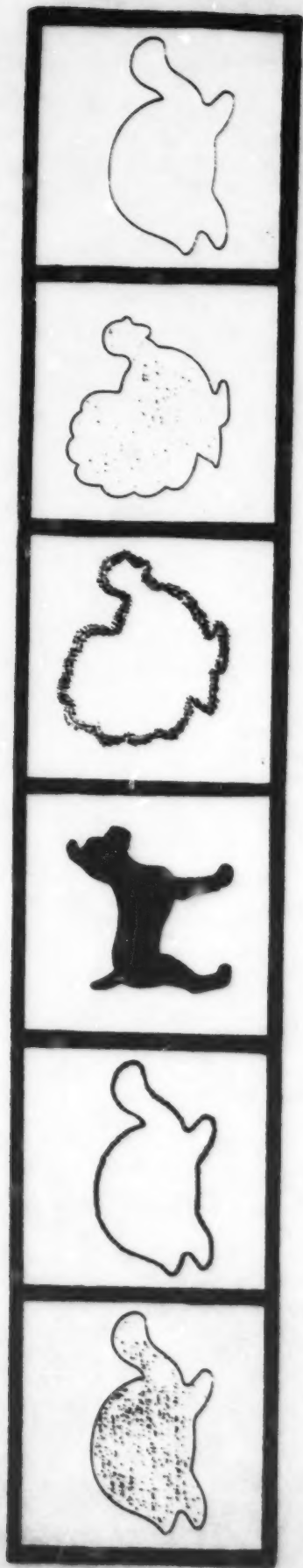


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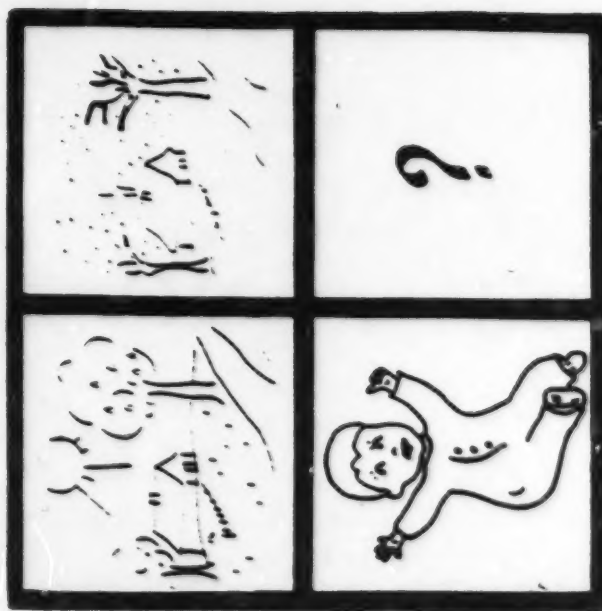


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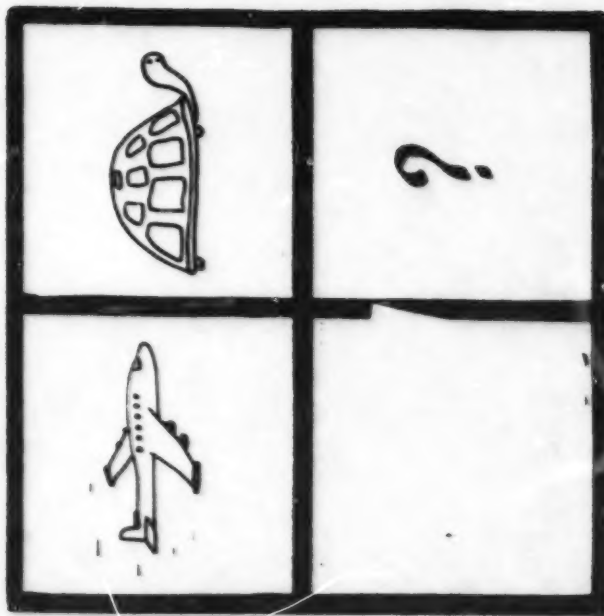
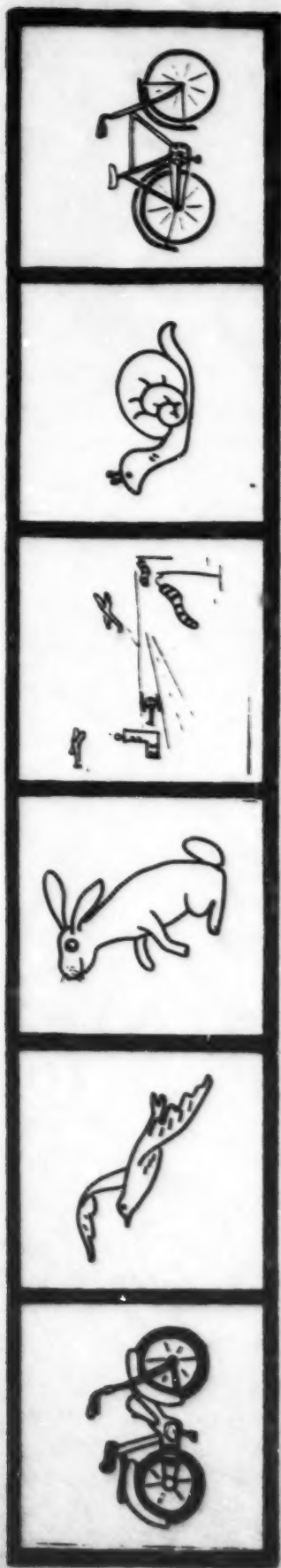


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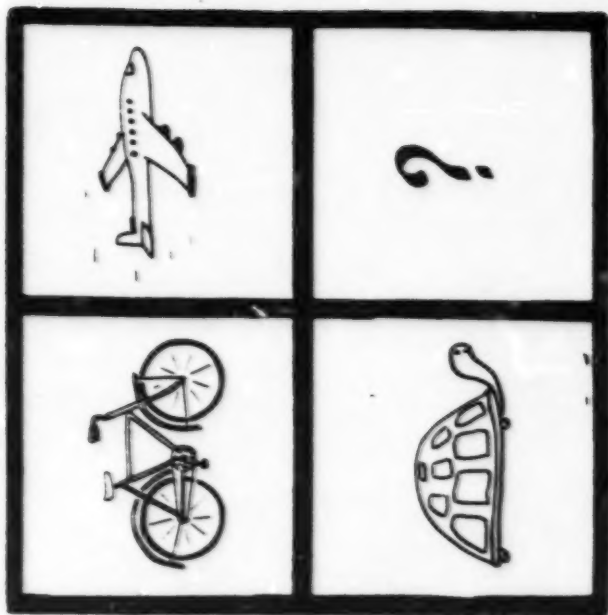
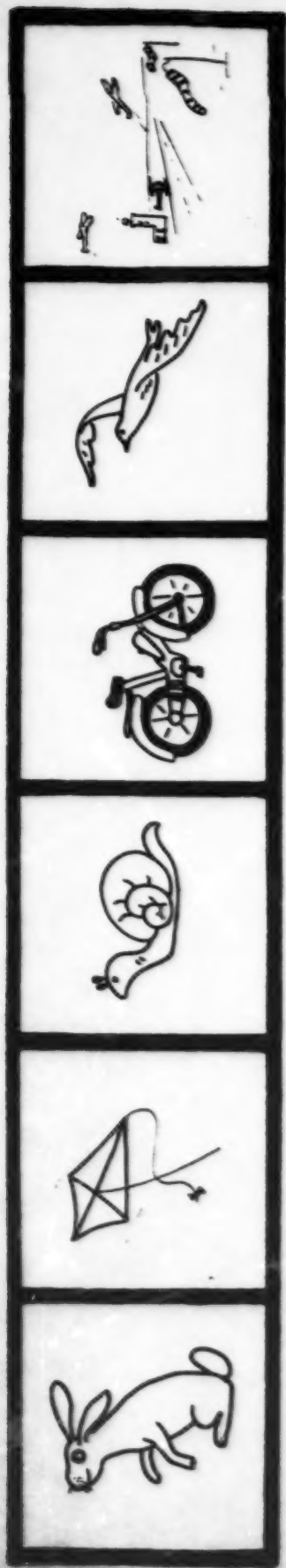


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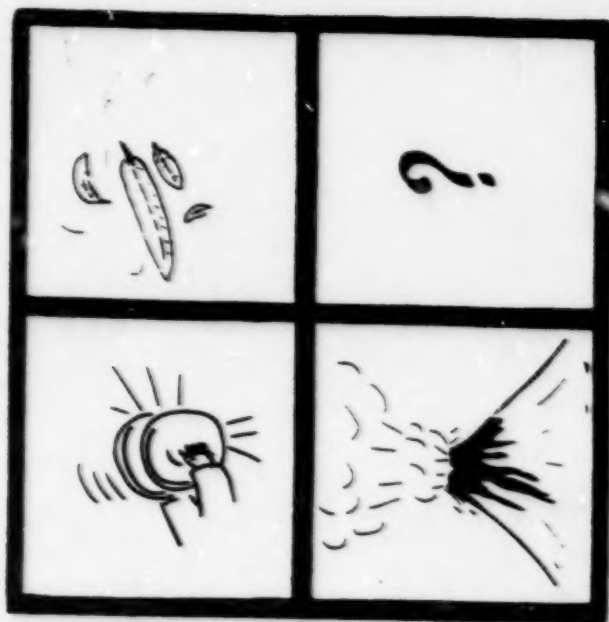
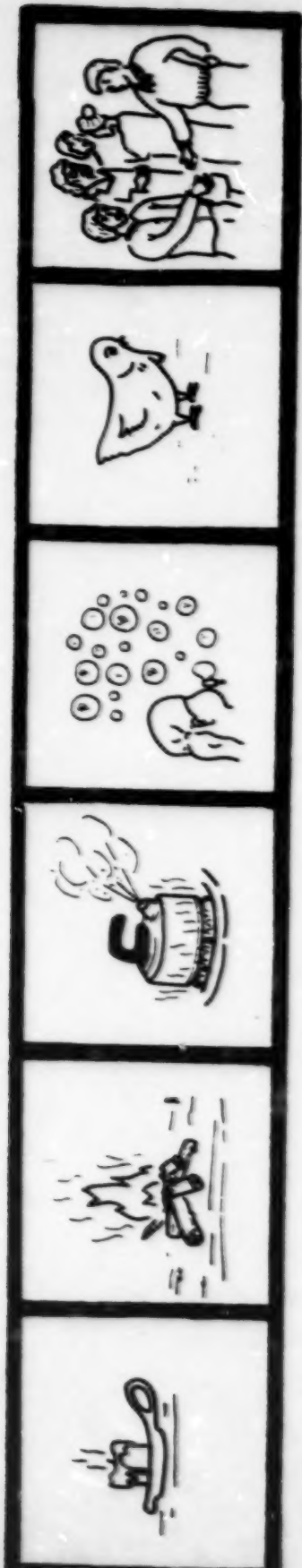


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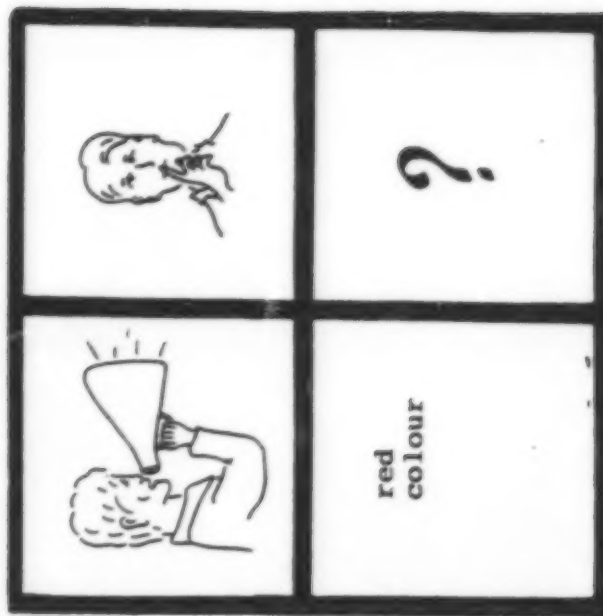
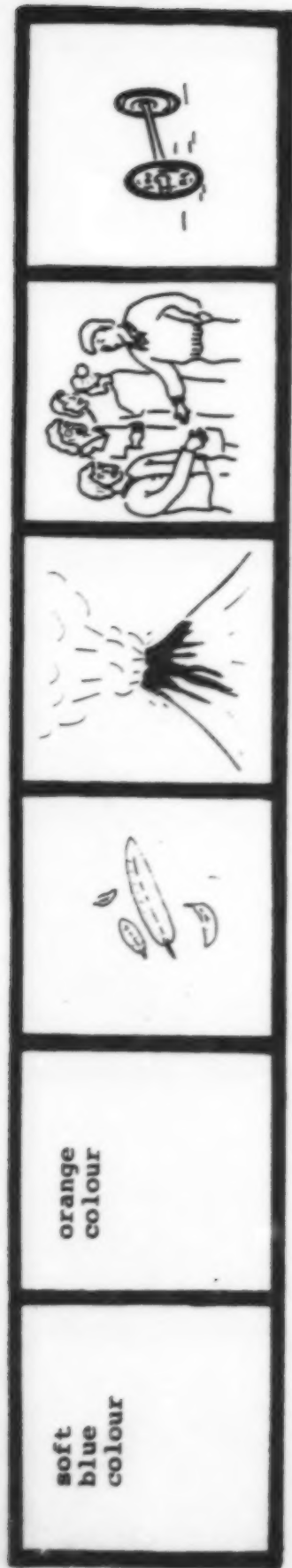


Figure 48.

